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NATIONAL ENERGY POLICY ACT OF 1988 AND GLOBAL WARMING

HEARINGS

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDREDTH CONGRESS

SECOND SESSION

ON

S. 2667

TO ESTABLISH A NATIONAL ENERGY POLICY TO REDUCE GLOBAL WARMING, AND FOR OTHER PURPOSES

AUGUST 11, SEPTEMBER 19 AND 20, 1988

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NATIONAL ENERGY POLICY ACT OF 1988 AND GLOBAL WARMING

THURSDAY, AUGUST 11, 1988

U.S. Senate,
Committee on Energy and Natural Resources,
Washington, DC.

The committee met, pursuant to notice, at 2:04 p.m., in room SD-366, Dirksen Senate Office Building, Hon. Timothy E. Wirth, presiding.

OPENING STATEMENT OF HON. TIMOTHY E. WIRTH, U.S. SENATOR FROM COLORADO

Senator Wirth. If the committee would come to order.

The Senate at the moment is in the throes of trying to complete the defense appropriation bill. Senator Johnston and others are going to try to be here, and we hope that we can welcome them. But we want to welcome all of you and thank you for coming today.

Little debate remains in the scientific community about the increased levels of carbon dioxide in the atmosphere. Global atmospheric concentrations of CO_2 have been steadily increasing since the advent of the industrial age. During the last 150 years, the level of CO_2 in the atmosphere has risen from 280 parts per million to 350. Since 1958, concentrations have increased by about 40 parts in that short period of time alone.

There is also no argument about the fact that certain stable levels of CO_2 are what make this planet inhabitable. If there were no CO_2 in the atmosphere, our planet might well be like Mars where temperatures are too cold to support life. Too much, as on Venus, would cause the oceans to boil away.

Since passage of the National Climate Program Act 10 years ago, the Department of Energy has been conducting research in the area of atmospheric CO_2. In its 1987 summary of this research effort, the Carbon Dioxide Research Division wrote on page 1, "the goal of this research program is the identification of possibly policy options for governmental action in response to changes in the atmospheric CO_2 concentration." What has the Department found? What has DOE decided, and what are they recommending to us?

Today's hearing is intended to review the response of the Federal Government to the evidence that has been accumulated for more than 15 years that the earth is warming at an alarming rate. Two weeks ago, with 17 of my colleagues, including the Chairman and a number of members of this committee, I introduced legislation to create an energy policy to address the issue of global warming.

We have with us two representatives of two of the agencies that will have to play an active role in crafting the policy that we in this country and working with our allies around the world and other countries must pursue.

Many of the scientists, as well as other experts, have been testifying for years about global warming. Congress has attempted to help to move the administration to develop strategies to combat the growing accumulation of greenhouse gases. For example, last year we enacted the Global Climate Protection Act requiring the President to formulate policies to address this issue.

Unhappily, it is difficult to find evidence of leadership from the current administration. Just last week DOE's assistant secretary for the environment, safety and health was quoted in the Coal News and in the Energy Daily as saying, "I think it is folly to try to come up with a solution to a problem before we know what the problem is." I hope that the assistant secretary was misquoted or that his statement was taken out of context. But, unfortunately, the pattern of the administration's response to the global warming issue is well summed up in these quotes.

Earlier this year 42 Senators wrote to the President urging him to call for a global climate convention at the Moscow summit and again at the seven nation economic summit held in Toronto earlier this summer. The administration's response was that it was too early to take such a stand.

In June at the Canadian Government's world conference on changing atmosphere, the prime ministers of Norway and Canada endorsed the notion of global climate convention. And again, the State Department responded by saying that such a step was premature.

One of the purposes of today's hearings is to underline the administration's responsibilities. Various Federal agencies must coordinate their efforts and lead, not stand by and let our climate change while we study the issue.

One of the first and most immediate steps we have to take is energy conservation. We have made impressive gains in the past, and we have other steps to take. Over the last 8 years, unfortunately our efforts in energy conservation from the Federal Government's perspective have decreased with a 45-percent reduction in energy conservation research and development. A similar sort of pattern exists in solar and renewable energy, but unfortunately over the last eight years that commitment has been cut by 85 percent.

In light of the global warming research and evidence presented to Congress in hearings over the last 8 years, warning of the potential devastating consequences of global warming, it is appropriate for us to ask how the administration is responding to this problem. What priority has been set by the Department of Energy and the EPA, and are the scientific agencies committed to resolving the most important questions about the greenhouse effect? And have we properly organized our agencies to respond?

We have introduced S. 2667. We need to know if, as stated in response to the Moscow letter, to the Toronto conference and in statements in the energy press, the administration believes that this legislation is premature. We have been told that the earth is already committed to a warming as much as 5 degrees Fahrenheit. Is it too early to act, to try to slow down further warming?

I hope we will not hear further calls for delay. Instead, I hope that we receive recommendations for how working alone and in concert with countries all around the globe we can slow the rate of emissions of the greenhouse gases and work to stabilize our climate before it gets away from us.

I look forward to receiving today's testimony on the global warming issue and on S. 2667, the National Energy Policy Act of 1988. This is a very complex and comprehensive bill, and I realize that our witnesses may not have digested all of its provisions, but it is a start and we welcome your thoughts, deletions, additions and criticisms. And we thank you all very much for being with us.

[The prepared statements of Senators Johnston, Wirth and McClure follow:]

Statement of J. Bennett Johnston
for
Hearing to Receive Testimony from Federal Agencies on their Response to Scientific Evidence of Global Climate Change

I am pleased to welcome you to this afternoon's hearing to receive testimony on the Federal agencies' response to the scientific evidence of global climate change and to receive statements on S. 2667, the "National Energy Policy Act of 1988". Testimony presented in June, in hearings before this Committee, contained sobering predictions regarding the degree and pace of global warming. Today's Greenhouse hearings underscore the rapidity with which the problem of global climate change is entering the public and political consciousness.

The issue of global warming and climate change is likely to be given considerable attention from Congress in the coming years, and this Committee will continue to keep abreast of the scientific evidence pertaining to the Greenhouse Effect in addition to exploring innovative policy solutions such as enhanced energy efficiency, renewable energy sources, and second generation nuclear technology in order to address this urgent issue. We believe the Committee's bill S. 2667, the "National Energy Policy Act of 1988", provides an excellent talking piece for the Committee's work on strategies to control emissions of carbon dioxide and trace gases.

Despite the uncertainty surrounding the exact pace and degree of global warming in the scientific community, the existence of this alarming phenomenon is almost certain. Failure to act on both the domestic and international fronts will likely have grave repercussions for our global climate. There is not much time before the effects of climate change, sea level rise, and habitat degradation will be felt not only in the United States, but in the rest of the world. The natural events of this summer, drought, record heat waves, and storm surges, have graphically demonstrated what conditions might be like for us under the predicted "Greenhouse" scenario.

It is therefore imperative that our Federal agencies take the lead in both the accumulation of scientific data relating to global climate change, and in the formulation of policies for mitigating the emission of CO2 and trace gases. Our nation's ability to cope with the unprecedented threat of accelerated global climate change will rest in large part on the ability of the Federal agencies assembled here today to respond in a timely and thoughtful manner to this daunting challenge. I look forward to both your prepared testimony and your comments and suggestions on the comprehensive legislation recently drafted by this Committee.

STATEMENT OF THE HONORABLE
TIMOTHY E. WIRTH
AUGUST 11, 1988

Little debate remains in the scientific community about the increased levels of carbon dioxide in the atmosphere. Global atmospheric concentrations of CO2 have been steadily increasing since the advent of the industrial age. During the past 150 years, the level of CO2 in the atmosphere has risen from 280 parts per million to 350 parts per million. Since 1958, concentrations have increased by about 40 parts per million.

There is also no argument about the fact that certain stable levels of CO2 are what make this planet inhabitable. If there were no CO2 in the atmosphere, our planet might be like Mars, where temperatures are too cold to support life. Too much CO2, as on Venus, would cause the oceans to boil away.

Since passage of the National Climate Program Act 10 years ago, the Department of Energy has been conducting research in the area of atmospheric CO2. In its 1987 summary of this research effort, the Carbon Dioxide Research Division wrote on page one, "the goal of this research program is the identification of possible policy options for governmental action in response to changes in the atmospheric CO2 concentration." What has the Department found, what has DOE decided and what are they recommending to us?

Today's hearing is intended to review the response of the federal government to evidence that has been accumulating for more 15 years that the earth is warming at an alarming rate. Two weeks ago, with 17 of my colleagues, including the chairman and a number of the members of this committee, I introduced legislation that would create an energy policy to address the issue of global warming.

We have with us today representatives from two of the federal agencies who will have to play an active role in crafting policy responses to this enormous domestic and international challenge. In addition, we have government scientists who must, as they have in the past, play an important role in providing the United States government with the scientific understanding it needs to respond to this issue.

Many of these scientists, as well as other experts, have been testifying for many years about this issue. Congress has attempted to help move the administration to develop strategies to combat the growing accumulation of greenhouse gases in the atmosphere. For example, last year, we enacted the Global Climate Protection Act requiring the President to formulate policies that address this issue.

We have introduced S. 2667, a comprehensive bill focussed on the issue of global warming. We need to know if, as stated in response to the Moscow letter, the Toronto conference, and statements in the energy press, the administration believes that this legislation is premature. We have been told that the earth is already committed to a warming of as much as 5 degrees Fahrenheit! Is it too early to act, to try to slow down further warming?

I hope we will not hear further calls for delay. Instead, I hope that we receive recommendations for how, working alone and in cncern with countries all around the world, we can slow the rate or emissions of the greenhouse gases and work to stabilize our climate before it gets away from us.

I look forward to receiving today's testimony on the global warming issue and on S. 2667, "The National Energy Policy Act of 1988." This is a very complex and comprehensive bill, and I realize that our witnesses may not have digested all of its provisions, but it is a start, and we welcome your thoughts, deletions, additions and criticisms. Thank you for being with us.

# # #

OPENING STATEMENT
SENATOR JAMES A. McCLURE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
THURSDAY, AUGUST 11, 1988 (2:00 P.M.)

NATIONAL ENERGY POLICY ACT (S. 2667)

Good afternoon. I wish to commend the chairman for reconvening the Committee's continuing hearings on the status of current knowledge regarding global climate changes and, in particular the "greenhouse effect". During our last hearings we received testimony from expert scientists. A review of today's witness list suggests that today's testimony will emphasize Federal programs directed at improving our understanding in this critical area.

Climate changes can have a great influence on human society. Their implications are global. What is unclear is how fast the changes are occurring, but what is clear is that this is an international concern. What also is clear is that there is no single cause and no single policy initiative that will completely mitigate current trends.

The world's reliance on fossil fuels -- coal, oil and natural gas -- clearly contribute to the "greenhouse effect", but so do international forestry and agricultural practices. As we proceed with the formulation of a strategy to deal with this critical problem greater international cooperation will be essential.

This Committee's jurisdiction encompasses many energy and natural resources concerns. Therefore it is only logical that S. 2667 would emphasize national energy policy concerns. The measure before us contains many issues that are elements in any national energy policy. But the principal concern of any national energy policy must be energy security, not mitigation of global climate changes, as important as they must be. That is not to say that we must not be concerned.

From this perspective I would encourage the chairman to undertake a series of hearing on each of the sixteen titles contained in S. 2667. Each of the proposals have their own strengths and weaknesses. Each raises different energy and environmental policy issues. So far the testimony received by the Committee on these matters over the last nine months has emphasized the problems rather than the solutions.

The proposals on the table focus on actions that the United States might take. But our actions alone will not mitigate current trends. I would urge the chairman to also expand these hearings to include testimony on the international concerns that must be reflected in any solution to this global, not national, problem.

I look forward to working with the chairman during the next Congress on this critical issue facing mankind.

Senator WIRTH. We are going to start the hearing this morning, and we will leave the record open, of course, for other opening statements by other members of the committee and others.

We will start the hearing today by asking two of our witnesses to join us: Donna Fitzpatrick and Stephen Schneider. Miss Fitzpatrick has had a very distinguished career at the Department of Energy—not career, but recent incarnation at the Department of Energy—and was recently confirmed as Associate Under Secretary of the Department. And, Donna, we are delighted to have you back with us today and greatly appreciate your commitment to energy and energy strategies.

Dr. Stephen Schneider is with the National Center for Atmospheric Research in Boulder, Colorado, and is no stranger to this committee or to these issues. And, Dr. Schneider, we are very grateful to you for coming across the country to be with us this afternoon.

We will include all of your statements in full in the record, and the record will be left open for other questions that may come up from other members of the committee after today's hearing.

With that, Donna, why don't you start and why don't you proceed in whatever way you feel would be most helpful to the committee. Thank you very much for coming up this afternoon. I am also aware of the fact that you have I believe a time limitation which is why we wanted to start with you as well. Thank you very much.

STATEMENT OF DONNA R. FITZPATRICK, ASSOCIATE UNDER SECRETARY, DEPARTMENT OF ENERGY

Ms. FITZPATRICK. Thank you, Mr. Chairman. I do have a full statement I would like to submit for the record, and I would like to make some opening comments.

It is a pleasure to be with you today to discuss the Department of Energy's activities and views on the important topic of global climate change. The greenhouse effect and the CO_2 concentrations in the atmosphere have been the subject of research attention at the Department of Energy for the last 10 years. In fact, the United States is the world leader in research in this area.

The evidence available from research to date on global climate change is sufficient cause for very serious concern even at the most optimistic end of the range of predicted impacts. This is of particular interest to the Department of Energy because U.S. fossil fuel use accounts for approximately 23 percent of the global total of CO_2 emissions resulting from combustion.

Our studies have also clearly demonstrated that there are still significant gaps in our knowledge of the greenhouse effect, gaps that must be reduced if we are to successfully address this concern.

Important feedback mechanisms which could reduce any projected warming are not well understood or incorporated into our models. Cloud cover, the role of oceans as a sink for carbon dioxide, and enhanced vegetative growth due to increased CO_2 are a few of these important uncertainties.

Another very important factor is the inability of the models to agree on the regional climate implications of the greenhouse gas concentration increases. Would the midwest, for example, receive more or less rain if global temperature increases?

Given these uncertainties, the government should continue vigorous efforts to reduce gaps in the data, refine modeling capabilities and develop options to reduce the accumulation of greenhouse gases or to mitigate or adjust to the result of climate changes.

Reducing scientific uncertainty is also crucial in building an international consensus because climate change is an international problem which must be addressed cooperatively among nations. For this reason, the United States Government with DOE's support has launched an important initiative to establish an intergovernmental panel on climate change to advise the World Meteorological Organization and the United Nations Environment Program on climate change scientific and policy research.

DOE's policy is to aggressively pursue resolution of scientific uncertainties and to further develop an international consensus. Also required now are vigorous scientific research technology development programs and analysis of policy options. At DOE we are pursuing precisely this course.

Our CO_2 research program is improving our understanding of CO_2 interactions with the atmosphere, the biosphere, oceans and the cryosphere.

Our super computing modeling leads the world and we are sharing that capability with the world research community.

Our technology development programs include aggressive efforts to reduce CO_2 emissions through development of more energy efficient technologies, renewable energy technologies, nuclear fission and fusion and advanced clean coal technologies.

With regard to S. 2667, I would like to make a few general comments while, as you pointed out, we are still reviewing the bill because it is very complex. And therefore we would like to make some further comments in writing if the committee desires.

The Congress has required DOE and other agencies to complete several studies, including studies of policy options for addressing the greenhouse effect. Further, there is not yet an international consensus of the timing or magnitude of regional changes or on the types of actions needed to address this issue. We believe, therefore, that it is important that these studies be completed to provide a sound basis for further efforts to address greenhouse concerns within the international context.

Secondly, we believe that the action of the type called for in S. 2667 would impose significant costs on some sectors of the economy, both within the United States and worldwide. Without further scientific understanding, we cannot be assured that these actions will be either effective or efficient.

In general, we believe that a technological solution is preferable to a regulatory one. A large scale regulatory program carried out unilaterally by the United States could only reduce greenhouse gas emissions by a very small fraction of the total emissions worldwide and could cost jobs and harm the Nation's international competitiveness without making substantial progress toward solving the problem. To address these concerns, we are taking a two-pronged approach.

Climate research and options analysis will contribute to the development of a sound basis on which an effective program of mitigation and emission stabilization could be established. Without strong international acceptance of a scientific assessment, it will be impossible to implement and sustain a truly effective program. This was the prerequisite for the successful adoption of the Montreal Protocol on ozone and chlorofluorocarbons.

Secondly, our present R&D program efforts will provide technology options which will not only help to reduce greenhouse gas emissions, but will also improve overall energy efficiency, create jobs and enhance America's competitiveness. We believe that this is a matter which warrants very serious concern and attention.

We appreciate the opportunity to review S. 2667 and to work with you and the committee on this issue. We intend to continue working with the Congress and other Federal agencies in a cooperative and constructive manner. We will be happy to provide more detailed comments on the bill if the committee desires once we have completed our review.

In summary, the scientific and policy uncertainties are such that the proper response is to vigorously reduce the scientific and policy knowledge gaps. DOE has a number of technology R&D programs underway and is pursuing scientific knowledge and policy analysis in concert with other Federal agencies and the international community. All of this will contribute to the resolution of this important concern.

The United States is the world leader in R&D related to greenhouse effect, and we will work in the appropriate international fora to obtain an effective international response.

Mr. Chairman, I appreciate the opportunity to appear before you today and to gain your advice on these matters. I will be happy to answer any questions you or the committee may have.

[The prepared statement of Ms. Fitzpatrick follows:]

TESTIMONY OF
DONNA R. FITZPATRICK
ASSOCIATE UNDER SECRETARY OF ENERGY
BEFORE THE
SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

THURSDAY, AUGUST 11, 1988

TESTIMONY OF DONNA R. FITZPATRICK
ASSOCIATE UNDER SECRETARY OF ENERGY
before the Senate Committee on Energy and Natural Resources

Thank you, Mr. Chairman, for this opportunity to address your committee on this important topic of potential climate change caused by the absorption of infrared radiation by certain gases in the atmosphere. These gases are carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4), tropospheric ozone and chloroflourocarbons (CFCs).

The greenhouse effect caused by the infrared absorption has been the subject of research attention at the Department of Energy (DOE) for the last ten years. As recently as December 1985, DOE published a four volume report which summarizes much of what is known and not known about the relationship between CO2 and climate change. That assessment has identified important future research areas so that policymakers can have the information necessary for formulating effective policies for addressing climate change.

Significant gaps exist in our knowledge of the greenhouse effect -- gaps that must be filled if we are to address the concerns raised by potential climate change in a scientifically supportable manner. The five major general circulation models predict that a doubling of CO2, (or the equivalent of a CO2 doubling when the other greenhouse gases are included) will lead to an increase in global mean temperature of between 1.5 and 4.5 degrees centigrade. At present emissions growth rates, this could occur by the middle of the next century. Since we currently may be near the peak of an interglacial period, such temperature increases as represented by this range are legitimate causes of concern. However, this temperature range is very broad and does not capture all the uncertainties. Important feedback mechanisms which would reduce any projected warming are not well understood or incorporated in these models. Cloud cover, the role of oceans as a sink for CO2, and enhanced vegetative growth due to increased CO2 are three of these important scientific uncertainties. For policy formulation purposes, another important factor is the inability of the models to agree on the regional climate implications of greenhouse gas concentration increases. Would the Midwest, for example, receive more or less rain if its temperature increases? This is a crucial consideration in developing mitigative strategies or in evaluating potential emissions stabilization policies.

In addition, increases in the amount of CO2 production have been greater than the corresponding increases in CO2 concentrations. Where has the extra CO2 gone over the last 140 years? Until we have a better understanding of the carbon cycle, it is difficult to know the effectiveness of potential emissions stabilization policies. These scientific uncertainties must be reduced before we commit the Nation's economic future to drastic and potentially misplaced policy responses.

Reducing scientific uncertainty is also crucial in building an international consensus on the need for action and on its appropriate form. Climate change is an international problem which must be addressed cooperatively among nations. No individual nation can substantially influence the rate of climate change using any set of feasible policies.

International cooperation on science and policy should develop together. Further, discussions on methods for policy evaluation, cooperative policy analysis where science is sufficiently robust, and preliminary discussions of the national interests of countries could contribute to developing an international consensus when both scientific understanding and policy analysis mature. For this reason, the United States Government, with DOE involvement, launched an important initiative last year to encourage the formation of an Intergovernmental Panel on Climate Change to advise the World Meteorological Organization and the United Nations Environment Programme on climate change research and policy analysis activities. This panel will be an influential forum for the discussion among governments on questions of science and policy. As in the Vienna Convention and the Montreal Protocol for the Protection of the Ozone Layer, the

U.S. Government provided international leadership by setting in place the appropriate mechanism for addressing climate change issues.

The evidence available to date is sufficient cause for serious concern, even at the most optimistic end of the range of predicted impacts. Therefore, the government should continue efforts to reduce gaps in data and to refine modeling capabilities. DOE and other interested agencies should also continue work to develop options to reduce the accumulation of greenhouse gases and to mitigate or adjust to the results of possible climate changes. These options must be analyzed for their technical feasibility and effectiveness as well as their economic impacts. Without carefully developed information of this sort, it will be impossible to arrive at the kind of national and international consensus that will be required for effective action. Particular caution should be exercised to avoid taking actions which would burden the U.S. economy or any sector of it or any geographic area in a manner which is unwarranted based on the available scientific evidence. Unilateral actions of this type could result in a loss of jobs and harm the Nation's international competitiveness. What is required is a vigorous scientific research, technology development, and policy analysis effort. The U.S. Government is pursuing precisely this path.

At DOE, a number of our programs have important roles in contributing to a reduction in greenhouse gas emissions and contributing to our understanding of climate change. We believe that the potential for global climate change and other long-term environmental issues can best be responded to by continuing development of a diversity of advanced energy supply technologies and technologies to reduce demand for energy. Several of these developmental programs presently being carried out will be discussed next.

DOE's Carbon Dioxide Research - Since the beginning of this program in 1978, DOE has published more than 80 technical and research reports on CO2 that bear directly on global climate change problems.

The goal of DOE's CO2 research is to develop the scientific knowledge base for governmental action and policy formation in response to changes of atmospheric CO2 and primary effects dealing with the earth's climate and biological systems. Achievement of this goal requires increased understanding of CO2 interactions involving the global atmosphere, biosphere, oceans, and cryosphere.

The Office of Energy Research has developed estimates of future atmospheric CO2 levels from energy models of the carbon cycle, including fundamental information about natural carbon exchanges among the atmosphere, the oceans and the terrestrial biosphere. This information is used to quantify changes of atmospheric CO2 concentration from human activities such as CO2 emissions from fossil fuel use and land clearing.

Knowledge of CO2 retained in the atmosphere is a key determinant in estimating the atmospheric CO2 concentration. Research has reduced the uncertainty of estimates of atmospheric CO2 retention from a scientifically-plausible range of 30-80 percent of human-related carbon release to the atmosphere to a "most likely" range of 50-60 percent. This relationship may change as global warming continues. An understanding of the global carbon system and its sensitivity to human and climate perturbations is crucial for reliably estimating future increases in the atmospheric CO2 concentration.

Research is also directed toward reducing scientific uncertainties and predicting of CO2-induced regional and seasonal patterns of climate change. The observational temperature data base has been expanded from only the Northern Hemisphere land area to a global data set, with a time span of about 130 years.

Climate models have improved. Model improvements include atmosphere-ocean coupling that provides for transport and storage of heat, and the source of moisture for global change model prediction of precipitation. Coupled ocean-atmosphere models are essential for estimating time rate of climate change.

Models agree well with each other and with data for estimating global average temperature and all models predict a warming for increased CO2, which is consistent with theoretical expectations. However, models do not agree with each other or with observed data for regions (e.g., for areas the size of a western state, differences as large as plus or minus 5°C are possible).

In addition, research will determine responses of crops and natural vegetation to increased concentration of atmospheric CO2 and to possible climate change. Specific objectives are: to determine fundamental effects of long-term exposure to elevated CO2 on plant physiology and growth; and to evaluate ecosystem responses to CO2 in terms of productivity and altered plant and animal composition of ecosystems. Subjects of study include crop and ecological systems with special attention to effects of CO2 on vegetation and the possible effect of CO2 on carbon balance of the terrestrial biosphere. Previous laboratory and field studies have demonstrated that increased concentration of CO2 fertilizes plants, enhances plant growth, and improves water-use efficiency.

Within the Office of Energy Research, major technology research programs are being conducted on advanced energy sources and processes such as fusion, hydrogen fuel cells, and superconductivity which could significantly improve energy efficiency.

Conservation and Renewable Programs

Ongoing energy conservation research and development programs seek to support the availability of more energy efficient technology options in the future. These programs relate to energy use in commercial and residential buildings, industry, and transportation. Improvements in end-use efficiency could reduce the growth in future energy demand by as much as 25 quads annually in 2010. Energy efficiency improvements and energy conservation are approaches to emissions control that will receive increased attention. Increased energy efficiency can help slow the rate of growth of fossil fuel used and provide additional time to develop alternative energy supply options.

Conservation programs, which aim at the development of new technologies to more efficiently use energy, affect all end user sectors -- residential, industrial, and transportation. New high temperature recuperators use waste heat to preheat combustion air for industrial furnaces and boilers and save over 50 percent of the energy used by non-recuperative equipment. Composite ceramic materials under development allow operation of recuperators in very high temperatures to recover waste heat at much higher temperatures than at present. New technologies for making steel and aluminum offer the opportunity of large reductions in energy consumption in the manufacture of those key materials. The development of high temperature ceramic material for use in new automotive engines will provide a much more efficient use of liquid fuels with a dramatic improvement in the emissions profile. The application of special coatings to glazing, advanced refrigeration systems, and thermally activated heat pumps will reduce energy consumption in residences. These kinds of technology developments presently underway should result in lower energy consumption and improved emissions characteristics without sacrificing operating efficiency or operating flexibility.

Specific research may also help contribute to reducing CO2 emissions. For example, the Industrial Energy Conservation Program is working on a method to reuse CO2 from fossil fuel combustion in enhanced oil recovery and other applications. All industrial applications currently use 1.25 to 3 billion tons of CO2 per year. Reuse technologies can have a small but significant impact on reducing future CO2 loading. Higher oil prices will encourage CO2 use in secondary and tertiary oil recovery.

Renewable energy technologies convert naturally occurring or reoccurring physical resources into useful energy forms, such as electricity, heat, or liquid fuels. The wind, solar, hydro, geothermal, biomass, and ocean resources which are the basis of these technologies represent a vast source of potential energy supply. Photovoltaics, wind, solar thermal, and hydropower technologies employ no combustion at the point of use and therefore entail no emissions, including CO2. The cumulative effects of biomass on CO2 loading are considered to be substantially less than the effects attributable to the use of fossil fuels. While the use of biomass contributes to the CO2 loading, the increased production of biomass per acre through well managed growth consumes CO2 from the atmosphere at an increased rate. Further, the root mass which remains after harvesting fixes up to 30 percent of the consumed carbon. Methanol and other liquid fuels produced from biomass have the potential for reducing transportation emissions and displacing fossil based liquid fuels. In our continuing review of this area, we will be paying special attention to the full fuel cycle CO2 attributes of biomass technology options. On a fuel cycle basis, an integrated biofuels energy system is probably the closest to being net zero for CO2 effects due to the CO2 absorption of the growing feedstocks.

Collectively, renewable energy plays a significant role in the current global energy mix, representing some 9 percent of domestic U.S. energy production. Many developing countries use substantially larger percentages, mostly because of woodburning. This contributes, in part, to the deforestation problem. The prospects for future growth in the use of renewable technology appear especially promising as research continues to improve their efficiency, economics, and reliability. Renewable energy use can reduce carbon emissions and give developing countries an attractive alternative to the use of fossil fuels or further depletion of forests.

As a longer term option to carbon-based fuels, hydrogen is a clean burning and versatile fuel. However, because hydrogen does not exist in a free state, current methods of hydrogen processing consume large amounts of primary energy which must be factored into the full fuel cycle assessment of CO2. Several promising hydrogen-processing technologies such as photochemical electrolysis might lead to cost-effective methods of producing hydrogen that do not themselves add to CO2 production so that they could be used in transportation and other energy uses.

Several of the electric energy system and storage technologies under development within the DOE program are primarily aimed at facilitating reliable and efficient operation of the Nation's electric power grid and the effective integration of renewable energy technologies into these grids. This will also improve the efficient use of base resources and thus reduce fuel use and emissions.

Nuclear Energy Programs

Nuclear energy in its existing form is a proven technology that currently provides nearly 20 percent of the Nation's electricity. There are currently 109 operable nuclear reactors, which generate electricity without producing CO2. Had the electricity generated by plants begun since 1973 been produced by oil-fired generators, it would have required approximately 3.5 billion barrels of oil, thus weakening the Nation's energy security position.

There are still improvements that can be made in nuclear reactor designs and the Department is sponsoring work to ensure that safe, environmentally compatible, and economic powerplants are available to utilities. We recognize the immediate need to shorten the delays involved in licensing existing technology, but also the need for a new generation of reactors with designs that resolve many of the concerns expressed today.

There are three advanced reactor technologies actively being developed by the Department: the advanced light water reactor (ALWR), the modular, high temperature gas reactor (MHTGR), and the liquid metal reactor (LMR).

The Department is focussing research in a joint program with industry on the development of the light water reactors that will be greatly simplified, incorporate passive safety features, certified by the Nuclear Regulatory Commission, and ready for commercialization in the 1990's without need for prototype demonstration.

The MHTGR Program, with industry and international support, is in preliminary design stage. This technology is very promising, but will require a demonstration of reliability and economics, thereby delaying commercial deployment until after the year 2000.

The LMR has the greatest potential to achieve significant breakthrough in economics, safety, licensability and waste management option. The Department has just selected General Electric's 465MW power reactors inherently safe module (PRISM) for a three-year effort to develop a conceptual design, and an option for two additional years of preliminary design. However, this technology will not be considered as a practical option for the marketplace until after the year 2000.

Fossil Energy Programs

Traditionally, DOE's advanced coal technology program has attempted to boost overall power generating efficiencies as a way of improving economics and reducing the cost of electricity to consumers. Efficiency improvements have taken on added importance because they are directly related to reducing CO2 and other greenhouse gases.

A conventional 500 megawatt, pulverized coal-fired power plant without a flue gas scrubber (burning 2.8 percent sulfur bituminous coal) emits approximately 2.75 million tons of CO2 per year. Adding a limestone scrubber to the plant -- to meet sulfur dioxide reduction standards imposed by the amended Clean Air Act -- actually increases the release of CO2 by about 3 percent while reducing the facility's power output.

Virtually all of the power generation technologies in DOE's Fossil Energy R & D and Clean Coal Technology Programs offer significant improvements over the 30-35 percent efficiencies of conventional coal-fired power plants equipped with scrubbers.

Significant reductions in CO2 emissions from the power generation sector of our economy are possible by developing and deploying more efficient, advanced fossil energy technologies in place of current technologies. Fuel use efficiencies and, consequently, CO2 emissions reductions can be further improved by applying many of these technologies to cogeneration applications where useful heat can be extracted along with electricity.

In addition, the Department is developing, through its Clean Coal Technology and Coal R&D programs, advanced retrofit environmental control technologies that retain higher overall plant efficiencies than a conventional flue gas scrubber. Technologies such as advanced coal cleaning, in-duct sorbent injection and gas reburning can reduce sulfur and nitrogen emissions without significantly lowering plant efficiency. The result would be a reduction in acid-rain-related emissions without introducing additional CO2 into the atmosphere as would be the case if conventional scrubbers were added to older powerplants.

It is also important to stress that many advanced clean coal technologies also reduce nitrogen oxides (NOx) in the range of 50-90 percent compared to pulverized coal plants. NOx is receiving increasing scrutiny relative to its role in the formation of tropospheric ozone (which also acts as a greenhouse gas).

The greatest percentage reductions in CO2 emissions from hydrocarbon combustion result from advanced technologies with improvements in efficiency and fueled with natural gas. Natural gas is the fossil fuel having the lowest CO2 emissions rate, yielding about half the CO2 of coal combustion for the same heat or energy produced.

In addition to its coal-based R&D program, the Department is also conducting R&D on the extraction of unconventional natural gas resources. Unconventional gas has the potential to make a significant contribution to the Nation's future energy supply by augmenting current conventional supplies. Currently, about one trillion cubic feet annually (about 5 percent of total annual gas production) is produced from unconventional gas resources. But if technological barriers can be removed, natural gas could be produced in greater quantities in the future from tight sands, shales and coal seams, and in the longer term, possibly from methane hydrates, deep source deposits, and biomass.

Environment, Safety and Health

The Office of Environment, Safety and Health has been expanding the capability of existing emissions projection models to incorporate some of the other greenhouse gases in addition to CO2. In this fiscal year, methane, which has energy and biogenic components, is being added to the model. Incorporating energy sources of methane release will improve our capacity to develop realistic scenarios of greenhouse gases. This work will continue in the coming year with the addition of other gases and sources of methane release.

Additionally, an energy data base for developing countries, which will be important sources of emissions in the future, is being developed. This work initially focuses on electricity generation in these countries, but future work will develop data on other fuel consumption.

Congress has recently directed four studies from the Office of Environment, Safety and Health on the relationship of energy policy and climate change, including an evaluation of Federal R&D activities on alternative fuels, policies to achieve large reductions in CO2, a greenhouse gas emissions inventory and policies to encourage private sector planning for climate change (H.R. 4567, Energy and Water Development Appropriation). These studies should be prepared on a very short time scale; planning is underway to begin those studies at the start of the new fiscal year. Policy analysis on climate change will be an important part of this Office's program in the coming years.

SUMMARY

Mr. Chairman, this completes my review of DOE actions to address the issues raised by the greenhouse effect. This matter will not be resolved quickly and will require a sustained effort on the part of governments and the private sector to understand the physical phenomena and fashion cooperative responses. I will be happy to answer any questions the subcommittee will have.

Senator **Wirth**. Thank you, Ms. Fitzpatrick.
Dr. Schneider.

STATEMENT OF DR. STEPHEN H. SCHNEIDER, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Dr. **Schneider**. Thank you very much.

Many people have thought of the greenhouse effect as a controversial issue, and I would like to state at the outset that the greenhouse effect is a scientific proposition and is not controversial at all. In fact, it is probably the best accepted scientific theory in the atmospheric sciences.

For example, if one looks at Mars with a very thin carbon dioxide atmosphere and its very cold temperatures, temperatures below that of most deep freezers, and looks at Venus with its very thick largely carbon dioxide atmosphere with temperatures hotter than most ovens, and then looks at the earth, that beautiful blue planet in space that we can see, with water in it whose temperatures are just right, we have the first direction as to the greenhouse effect. In fact, some of us have referred to this as the Goldlilocks' proposition in the sense that earth is just right and the other two are far off.

The reason that that is understood is that the thick atmosphere of Venus and the thin atmosphere of Mars are responsible for allowing solar energy to more easily penetrate through to the surface, as is the earth's atmosphere. Then energy can escape back out, a special kind of energy called infrared energy. Venus is much more efficient at trapping that energy and reradiating to the surface; Mars, the least efficient; and the earth in the middle.

So, from that point of view, the greenhouse effect is not controversial at all. In fact, the earth, if we remove the envelope of gases like water vapor and carbon dioxide, would have its temperatures many times colder than that difference between now and the ice age, and life as we know it would not be possible. So, we in a sense owe our present biological existence to the greenhouse effect.

So, where is the controversy? The controversy is over whether an increment to the greenhouse effect on earth from human activities is going to make the planet 1 or 5 or 10 degrees Fahrenheit warmer in the next 20 or 50 or 100 years. It is over whether it is going to be drier in Iowa or hotter in India and when. And it is over what that means and ultimately what to do about it. So, we need to make clear at the outset the nature of those uncertainties, and I have in the written record elaborated them in more detail.

What we need to do also is recognize that the climate has natural fluctuations. I have probably received 10 phone calls a week in the last several months and in some weeks 10 a day from journalists and others trying to ask is this heat wave and drought finally the manifestation that you and others have been talking about for 15 years. One reporter actually asked me are you ready to say I told you so. And while that makes one smile, I said I told you so almost.

The best metaphor I can think of to try to describe the event of today, for example, is to use the metaphor of dice. Think of the anomaly that one gets in weather from one year to the next, whether you have a hot summer or a cold winter, at just the natural manifestation of the role of climatic dice. Instead of 12 faces, these metaphorical dice would have 1,200, and they have some colds and some hots and some dries and so forth. And nature rolls them by simply redistributing energy among the atmosphere and the oceans and the glaciers.

But what people are doing is they are erasing some of the colder faces and adding some of the warmer faces. That is what our physics tells us we should be doing. And our modeling tells us we may also be loading the dice on drier mid-continental conditions in the summertime. That is more controversial because it is tougher to do regional details.

So, therefore, when one asks is this particular year's drought caused by the greenhouse effect, you have to say you can never assert that one global forcing like increased gases can make one year warm, but you can say it is the kind of event which our theory suggests might happen with increased frequency, and that it is a little bit warmer than it would have been without the greenhouse effect. And, therefore, it may have exacerbated the drought. And if one doesn't like this kind of condition, then one should seriously reflect on whether one wants rapid climate change.

And that leads me to want to describe now some of the greenhouse effect issues, what are the scientific questions that Secretary Fitzpatrick referred to over which we have uncertainty and what are the things that we know something about and whether that ultimately justifies Federal action now.

You can decompose this problem of the greenhouse effect into several stages. The first stage is how much greenhouse gases, carbon dioxide, methane, nitrous oxides, fluorocarbons, are people responsible for putting in the air. We know this is virtually a certain fact that something like 25 percent more carbon dioxide is in the air today than it was before the Industrial Revolution. And we know that because in the ice masses in the poles, gases have been trapped from those dates and one can simply analyze the composition of gas bubbles trapped in ice cores and determine what the amount is. So, we are about 25 percent more carbon dioxide.

Much of that can be accounted for by the burning of fossil fuels, coal, oil and gas, and some of it by deforestation. In particular recently deforestation of the tropics may have been a contributor to something like one-fifth of the recent increase.

But in order to project the future, we have to be able to make not scientific assumptions, if you will, but social science assumptions, and we have to try to predict what people will do. The total CO_2 emission is really equal to a product of three terms. The first term is the CO_2 per technology. A technology like photovoltaics doesn't produce CO_2 technology like the burning of fossil fuel does. The same nuclear energy doesn't produce CO_2 either except to the extent that nuclear or photovoltaics have to be built by a subsidy for fossil fuel. But the technology is something over which we have control.

The second component in this multiplier is the technology per capita, in essence the standard of living of a country. Most countries want more technology per capita if it reflects a better standard living, and ultimately the population size. So, to project future emissions, it is the product of the emission per technology times the technology per capita times the total population size.

And, indeed, what people do is make scenarios of this in order to project the future. Well, it is impossible to know which scenario is accurate because different people can have legitimately different opinions about any of those three things, but we can do plausible scenarios. And despite the fact that this confuses us in making forward projections, it gives us an opportunity for action. And I think that many of those actions are spelled out in the act, which I will get to in the end of my testimony, but actions that deal both with technology, with standard of living and with population. And to view the problem without recognizing the total comprehensiveness of those three components is not to view the problem in its totality.

The second question is once we make some scenario of how much of these gases there will be in the future, what deforestation activities people will have and so forth, we then have to say how does nature dispose of it. Right now we know that of the carbon dioxides something like half of what we inject seems to disappear from the system. We know that because we can pretty much account for how much is being injected from fossil fuels, and we have some idea about what comes from trees and so forth.

So, where does that half go? The bulk of people think that it goes into the oceans. Some think that the trees are going to grow a little bit faster because CO_2 enhances photosynthesis. Remember, that is the process where carbon dioxide is removed from the air by green plants through sunlight and so forth. But the debate about the carbon cycle generally tells us that something on the order of a doubling of CO_2, anywhere from 50 to 100 years in the future based upon typical economic projections.

Well, after that, we go to the next stage in this diagnosis which is how do we estimate what happens if we have this doubling of CO_2 or some other kind of increase, and we do that by using a combination of techniques, empirical ones. We look at the earth's history, look way back to times of the ice age and even back to times of the dinosaurs when the planet was either colder or warmer and try to understand that.

But we also ultimately have to turn to a tool that can do what-if experiments because without the ability to do what-if experiments, it is impossible to track these plausible scenarios of the future, and it is difficult to do policy analysis on whether we should or shouldn't try to control these gases. And the tool that we use is a mathematical model or a climate model. And there is a whole variety of them run both in this country and in many other countries, and they have been doing this now for over 20 years. In fact, the problem was first done over 100 years ago, and it is only in the past 20 to 30 years that modern techniques have been applied. And they all are in rough agreement to a factor of two that if CO_2 were to double and we had a long enough time to wait for the system to come into a new balance, the global temperatures would rise on the order of 2 to 5 degrees Celsius.

Now, CO_2 is not the only gas of interest. There are these other trace gases I mentioned, methane and nitrous oxides and fluorocarbons. And if you take all those little ones and you add them together, they are effectively on the order of doubling the CO_2 amount. They are about as equally effective as CO_2.

So, we could be seeing temperature changes in the next 50 to 100 years as much as 5 or more degrees Celsius if you want to believe what these models do. And to put some perspective on that, the last ice age, which ended about 10,000 years ago, was something like 5 degrees Celsius colder than the present. So, we are talking about adding another 5 degrees on to the climate system in the time frame of a century.

Senator WIRTH. If I might, let me briefly interrupt. We have a vote on the final passage of the DOD appropriations bill. So, I am going to have to turn into a pumpkin momentarily and go over and do that and come back again. Maybe we could pick up at that point on what happens if CO_2 doubles, it seems to me, that would be a good breaking point.

In the meantime, why don't we do this. Why don't we get our other three witnesses to come up here, and that would open up three chairs, and maybe there are some other chairs back here that are empty. And we can at least take care of a few people who are standing in the back.

I will be right back.

[Recess.]

Senator WIRTH. The committee will come back to order.

With some surprise, the Chairman finds himself without a witness from the Department of Energy. I guess it is getting hot outside and hot inside as well probably as the afternoon goes along.

Dr. Schneider, why don't you go ahead?

Dr. SCHNEIDER. Yes. I was saying that the temperature difference at the present time and an ice age is about 5 degrees Celsius on a global average. Of course, locally like in the middle Atlantic states, it might have been 10 or 20 degrees colder. But if you just simply do a scaling of the time it takes for nature through its own devices such as the interglacial cycle to warm up the planet, and you assign liberally a 20 degree change in New England, for example, from 15,000 years ago to 5,000 years ago, that is something on the order of 2 degrees Celsius per millennium as an average rate of change. And the kind of rates that we are talking about from our basic physical theories and models is something on the order of 2 to 6 degrees Celsius in the time frame of a century. So, we are something on the order of 10 to 30, 40 times more influential on changing the rates of climate change.

Now, I have been careful not to tell you whether I am going to pick the 2 number or the 6 number because, indeed, what Secretary Fitzpatrick said about uncertainty is true, and there certainly is a degree of uncertainty at the level of factor of 2. I don't think there is a degree of uncertainty at the level of factor of 10. And I wanted that rate issue clear and well understood.

The next issue looking at the scale of greenhouse effect questions is supposing we had some knowledge that the globe might warm up by 3 degrees. Already there is good evidence it has warmed up about six to seven-tenths of a degree C, in other words, a little over 1 degree Fahrenheit.

Now, what would that mean regionally? What happens in Iowa? Well, again one uses climatic models, for example, and some of those models say it gets wetter. Some of them say it gets drier, but they all say it gets hotter. And one of the principal reasons that the end of the summer always has much less soil moisture than the beginning is that the soil has been exposed to that heat of the summer. So, evaporation and evapotranspiration from plants would most likely go up in a condition of warming.

Therefore, the models are probably not off base in suggesting that there is a good chance that it would be drier in mid parts of continents unless, of course, there was enough precipitation in addition to that which we now have to compensate for that extra evaporation. That is where you get statements like dry and that is why some people have said the present drought resembles some of the climate models.

Now, what might that mean is the next part. Once you have a regional scenario of climate change—and I will argue that those regional scenarios have to be multiple. We can't pick any one device and say this one particular model's result is the truth. We need to look at several of them and continuously refine them.

We then have to ask what difference would it make if such a scenario occurred. And warmer in the midwest and drier certainly is a difference that is tangible to most people just from this year alone. If this were sustained and we knew in advance it was happening, there might be some mitigation strategies we could do. We might have some irrigation and other such things. But it would be hard to imagine that hotter and drier would, on balance, be beneficial to agriculture in that part of the world.

It might open up other lands to the north and, indeed, a number of economists have said, well, maybe what we will lose in Iowa, we will gain in Minnesota. And that kind of debate takes place now, but there has been, from the research point of view, much less study of that kind of question than there has been of whether the physical science is valid or not.

We have almost been asking the question in reverse. I would have preferred to say so what if the climate changes and then figure out what that means almost in advance of doing the physical science. But we have done it in reverse, and I think the reality is we should do both and do them both vigorously.

Finally, we reach the question of what should we do about all this. And that is based in large part upon environmental and societal impact assessment which is the area that has only recently been done. And there are three categories of policy response: mitigation, adaptation and prevention.

Mitigation some people would consider climate control. Couldn't you use a fleet of supersonic or other kind of a high flying aircraft to spread something like soot up in the stratosphere to block out sunlight and counteract warming. This has been seriously proposed by a Russian and by a number of other people. And my answer to that is if we have a factor of two uncertainty in whether the greenhouse warming is 2 degrees or 6 degrees, we have the same factor of two in the cooling, so you have a 25 percent chance that we have overestimated the warming by a factor of two and underestimated the cooling. You end up with a cure worse than the disease. Anytime one intervenes in nature, you also run the risk if the climatic dice give you some very nasty faces of being culpable for it even if you didn't do it.

Anyhow, there are people who will, I believe, increasingly propose such countermeasures. And I think that our political institutions and our legal institutions that deal with those are very, very immature.

The second category is adaptation. It is one that tends to be favored most by, to use a word, economists. At a recent meeting an economist got up following a talk that I and a number of others had given and suggested that the greenhouse effect issues and the rates questions mentioned are of a very serious concern, but until we can give specific details of exactly where it is wetter and drier and exactly how much extra air conditioning loads we will have and exactly what happens to agriculture, they can't apply cost-benefit analysis to figure out the winners and losers. So, therefore, the appropriate action was to study.

And I recall saying that I was sorry. And I guess I wasn't being facetious; I was being nasty. I was sorry that he wasn't a principal advisor to our military and the Soviets because, since we don't know from which part of the compass the missiles may fly or where the next terrorist incident is, we could spend $3 billion on studies and save $300 billion on hardware and on armies. Most people, on the other hand, do believe in strategic protection against plausible futures that we don't like. In addition, why would we buy insurance because we don't know if we are breaking our leg or going to have a kidney stone, so let's wait until it happens and then we will buy insurance.

And the argument that I believe is more appropriate for a problem, such as the greenhouse effect or also ones such as the fluorocarbon stratospheric ozone that Dr. Watson will talk about, is to recognize the magnitude of the change that we are bringing relative to natural changes. The opinion of the vast majority of scientists I have tapped, is sufficiently large and there is concern that we are in a sense insulting the environment much faster than we can understand it. And therefore the policy issue is are there things we can do to slow it down that also are high leverage, that also make sense. Some of us have called this the tie-in strategy, and you mentioned some in your opening remarks.

The single most obvious one and one you focus on at length in the Energy Act is energy efficiency. Energy efficiency does many things. It doesn't just simply reduce the greenhouse effect, slow it down, it also reduces acid rain. It reduces local air pollution crises in cities and populated areas, and it reduces dependence on foreign supplies. At the same time, it makes the energy component of our manufacturing costs lower and, indeed, the energy component of U.S. manufacturing costs is higher by perhaps a factor of two than many of our European competitors and even more than that relative to the Japanese. So, in the long term it can make us more competitive.

But like any insurance, there is a premium, and that premium does have to be paid up front. And I would argue that no prudent society spends all of its resources hedging against every outcome that anyone with a placard comes along and suggests. But this isn't simply a group of placard carrying nutty scientists. There is a large consensus that there is a very rapid change relative to nature afoot. And there are mechanisms to slow it down, whereas even if this whole thing proved to be what I once called an infrared herring, we still would have benefit——

[Laughter.]

Dr. **Schneider** [continuing]. We would still have benefit from those kinds of strategies.

Other examples of developing alternative energy sources and dealing with population growth and deforestation in tropical countries and helping countries like China with a massive amount of coal to find alternatives.

Now, finally, to conclude, looking at the act, the act mentions many of the things that I have just said. It deals with the comprehensiveness of the program from the initial technology component to the standard of living component to the population component. I suspect, if it hasn't already happened, that there will be many people who will oppose it on the grounds that it is just too big to deal with.

But my response to that would be if we don't diagnose the problem at the level of all the related issues, how are we going to find solutions. Solutions have to be commensurate with the nature of the problem. And I feel that that kind of omnibus approach is realistic with regard to the nature of this problem.

Finally, the part of the act that I like the best is it does not have platitudes about scientific uncertainty as an excuse to avoid action. The sorts of actions that are high leverage such as energy efficiency or developing alternative crop strains or making safer and more environmentally benign technologies make good sense regardless of the greenhouse effect, and they slow it down. And as I have tried to argue from a scientific point of view, what I am most frightened about with regard to the greenhouse effect is the rapidity with which we are changing things relative to nature. So, slowing it down makes to me very good sense. And when you can do that in a high leverage fashion, that would seem to me an appropriate function of government.

And finally, the other thing about the act is it cuts across so many lines that from the metaphor of my area in science, this problem, the greenhouse effect problem for example, issues of global warming – they can't be solve by oceanography or meteorology or astronomy or biology alone. They require those disciplines to interact. And it is something that academics are only recently beginning to get to learn how to do, which is to work together in interdisciplinary teams.

We haven't solved the problem of promoting to tenure people who do that kind of work. We haven't solved the problems of how easily we can get money available to them through institutions such as the National Science Foundation, but we are making progress.

But we are not the only ones who are guilty of this. I think when you look at this very institution which has committees on energy and committees on agriculture and so forth, that you too have to figure how to get those committees to work together on an issue that is truly crosscutting, such as the greenhouse effect is. And I again applaud the bill for recognizing that and would be happy to continue working with you in any way to try to get those connections made so that we can address the problem at the level at which it exists.

Thank you.

[The prepared statement of Dr. Schneider follows:]

THE GREENHOUSE EFFECT:

DO WE NEED MAJOR FEDERAL ACTION NOW?

Testimony of

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P.O. Box 3000
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on

Federal Agency Response to Global Climate Change:
The National Energy Policy Act of 1988

before

U.S. Senate Full Committee on Energy and Natural Resources

Thursday, August 11, 1988, 2:00 pm

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Within the past ten months the cover stories of both Time and Newsweek have featured global warming from the greenhouse effect and ozone depletion from industrial chemicals. The intense heat, forest fires, and drought of the summer of 1988 have ignited an explosion of media, public, and governmental concern that the long debated global warming has arrived -- and prompted some calls for urgent actions to deal with it. The sudden discovery of the Antarctic ozone hole has caused similar concerns. A stiff "I told you so" to scientific doubters and policy delayers might offer some measure of personal satisfaction to those of us who have been advocating a global response to atmospheric change for the past 15 years (e.g., see Schneider and Mesirow, 1976). However, scientific caution constrains me to respond instead: "I told you so -- almost." What, then, can be said about whether the climatic disruptions of the 1980s are of natural or human causes?

TEMPERATURE CHANGE OF THE PAST CENTURY

The hemispheric average of interannual temperature variability is less than a half degree C, but locally the year-to-year variability can be much larger. For example, warm or cold winters can differ locally by many degrees from hemispheric averages, and interannual precipitation variability can be many times different from hemispheric average variability. Now, if increasing greenhouse gases were to warm hemispheric or global temperature a few degrees, this large-scale change could be non-uniformly distributed in space and time -- as it has already been in previous observed trends. For example, Figure 1 from Hansen and Lebedeff, 1987, shows climatic trends in which high latitude temperatures can be seen to vary more than trends at mid- or low latitudes.

Trends at some latitudes or in some seasons could be enhanced or even have opposite signs relative to annual, global trends.

Reconstructing the earth's temperature during the past century is not simply a matter of adding up all of the thermometers that were available. First of all, many records are not continuous at the same place, some thermometers having been moved from centers of cities to airports, for example. Or cities may have grown up around thermometers, warming the local climate by an "urban heat island", even though the countryside is unaltered. Considerable care, therefore, needs to be taken to be sure that each record is a valid measure of the temperature average of an area or has been corrected for such spurious effects as urban heating. Furthermore, thermometers are not uniformly distributed around the world but are concentrated in highly populated parts of industrial countries and are often missing from remote land and ocean. The non-uniform distribution of thermometers samples variable climate changes inhomogeneously, producing a bias such that the actual trend in temperature over a latitude zone could be incorrectly deduced, as once noted by Schneider and Mass, 1975.

Inevitably, such "spatial sampling errors" creep into all records of hemispheric and global temperature trends, and requires some care to minimize these errors. Such groups as those led by James Hansen at the Goddard Institute of Space Studies (GISS) and by T.M.L. Wigley at the Climatic Research Unit (CRU) in East Anglia, have assembled hundreds of temperature records over the past century. They attempt to account for the inhomogeneous sample of stations by assigning to each thermometer a mean and an anomaly from that mean over the lifetime of its record. Then, the anomalies are apportioned to nearby grid points to minimize problems of a density of thermometers in certain parts of the world and scarcity in others. Although their techniques cannot entirely eliminate spatial sampling errors and some biases from locality, they are the state-of-the-art in reconstructing the climate of the past century, probably accurate to a few tenths of a degree C on a hemispheric basis. This error, I believe, is likely to be less than the magnitude of the trend reported over the past century by both GISS and CRU.

The GISS and CRU reconstructions up to the mid-1980s, including records from ships, corrected for such problems as heating of decks during the day or heating of water in engine intake tubes, are compared in Fig. 2. Despite the pitfalls mentioned earlier, the two groups have produced records that may differ in individual fluctuations from year to year, but both agree on the two most salient features: (a) the approximately 0.7°C secular trend in global average during the past century and (b) several warm years bunched in the 1980's (1987 was the warmest year in the record Hansen has noted).

Seasonal or annual mean hemispheric or zonal temperatures are, of course, not the only important measures of climatic change. Combinations of variables or statistical measures chosen as "variability variables" should: (1) be chosen for some phenomena of interest; and (2) help detect some plausible scenario of climatic change. Hundreds of combinations of climatic variables could be important to some environmental or societal activity. For example, the probability of frost at a certain location and season is critical for agriculture. Extended hot spells above, say, 35°C, potentially sterilizes corn and reduces yields regardless of soil moisture conditions. This was a common experience in 1988. Other measures of variability, such as warm, relatively snowless winters punctuated by spells of intense cold, are implicated in damage to temperate forests. In other words, in addition to the usual array of mean climatic variables such as monthly average temperature, pressure, precipitation, humidity, solar radiation, and wind, we also must study climatic variability for time scales as short as a day.

Finally, analysis of any variability variable should help in the detection of any anticipated trend from the natural background variability or noise caused by vacillations of the troughs and ridges of the circumpolar vortex, "jet stream". Such vacillations cause regional patterns of anomalies, such as seen in a Palmer Drought Map (Fig. 3) for the extremely dry 1988 summer. Analyses of the "signal-to-noise" ratio of some anticipated change (e.g., temperature rise from CO_2 doubling) divided by some measure of natural variability (e.g., standard deviation of interannual temperatures) is necessary to determine the probability that any signal detected in real data (and in climatic models) is not natural climate noise.

LOADING THE "CLIMATE DICE": HAS A GLOBAL WARMING SIGNAL BEEN DETECTED

Another way to fathom the signal-to-noise problem of detecting a global warming trend against the background of natural climatic fluctuations is by metaphor to games of chance. One can think of the fluctuating weather as faces on a giant pair of "climate dice" -- 1,200 faces rather than 12 to keep this metaphor closer to reality. Warm summers, cold falls, droughts, floods, and so forth are then simply random natural events controlled by the "luck of the roll". However, most climatologists, I believe, do agree that the current evidence is strong that human activities are loading the dice with many more warm faces, and perhaps a few more dry ones, too -- at least some of our modeling results suggest mid-continental droughts from a sustained greenhouse warming. Whether the 1980s warmth or the 1988 heat and drought are "proof" of loaded climate dice or simply bad luck from perverse nature is no easier to establish than whether two or three snake-eyes in a row with conventional dice prove them loaded rather than a few rare rolls.

Different tastes cause some people to accept the reality of a hypothesized climatic change at a low signal-to-noise ratio, whereas others might not believe in the reality of the change until a large signal has persisted for a very long time (e.g., Karl, 1988). Although two scientists are viewing identical records and computing identical signal-to-noise ratios, one may claim that the signal of an enhanced greenhouse effect is already detected, another equally competent, honest investigator may argue that it is statistically insignificant. Indeed, such confusing and contradictory statements from experts are frequently found in media accounts of global warming. Quite simply, accepting any particular signal-to-noise ratio as "proof" of global warming reflects the personal judgment of the investigator, and thus different scientists will retain or shed their scepticism in different degrees and at different times. However, the global warming "experiment" now underway is not only an academic debate, for we and other inhabitants of Earth will have to live with the outcome should too much scientific skepticism cause further delays in implementing actions to prevent or adapt more effectively to global warming.

SCIENTIFIC ISSUES SURROUNDING THE "GREENHOUSE EFFECT"

It is helpful to break down the greenhouse effect issue into a series of stages, each feeding in to another, and then to consider how policy questions might be addressed against the background of these more technical stages. We'll focus here on the CO_2 greenhouse issue for the sake of simplicity, although a similar series of stages applies to other greenhouse gases or atmospheric questions.

Behavioral Assumptions. The very foundation of the problem is behavioral assumptions that must be made in order to project future use of fossil fuels (or deforestation, since this too can impact the amount of CO_2 in the atmosphere). The essence of this issue then is not chemistry or physics or biology, but social science. It depends upon projections of human population, the per capita consumption of fossil fuel, deforestation rates, aforestation activities, and perhaps even countermeasures to deal with the extra carbon dioxide in the air. These projections depend on issues such as the likelihood that alternative energy systems or conservation measures will be available, their price, and their social acceptability. Furthermore, trade in fuel carbon (for example, a large scale transfer from coal-rich to coal-poor nations) will depend not only on the energy requirements and the available alternatives but also on the economic health of the potential importing nations. This in turn will depend upon whether those nations have adequate capital resources to spend on energy rather than other precious strategic commodities--such as food or fertilizer as well as some other strategic materials such as weaponry. Total emissions can be expressed by a formula termed "the population multiplier" by John Holdren and Paul Erhlich nearly two decades ago. Applied to the CO_2 issue it states:

$$\text{Total } CO_2 \text{ emission} = \frac{CO_2 \text{ emission}}{\text{technology}} \times \frac{\text{technology}}{\text{capital}} \times \text{total population size}$$

The first term is engineering, the second standard of living and the third demography.

In order to quantify the future we can make scenarios (such as seen on Figure 4) which show alternative CO_2 futures based on assumed rates of growth in the use of fossil fuels. Most typical projections are in the 1-2% annual growth range for fossil fuel use implying a doubling of CO_2 (to 600 ppm) in the 21st century. There is virtually no dispute among scientists that CO_2 concentration has already increased by some 25% over the past century. (Other greenhouse gases like CFCs, methane, nitrogen oxides, etc. could, taken together, be as important as CO_2 in the future greenhouse effect, but these have complicated biogeochemical interactions; thus, we'll call all greenhouse gases taken together "CO_2" for the present. However, this implies that what is projected for CO_2 alone on Fig. 4 will *underestimate* the total greenhouse gas buildup by roughly a factor of 2.)

The Carbon Cycle. Once we have some plausible set of scenarios for how much CO_2 will be injected into the atmosphere we then need to determine what interacting biogeochemical processes control the global distribution and stocks of the carbon. This involves uptake by green plants (since CO_2 is the basis of photosynthesis, more CO_2 in the air means faster rates of photosynthesis), changes in the amount of forested area, what is planted, and how climate change affects natural ecosystems on land and in the oceans. As a concrete example of how large natural climatic change (ice age to interglacial formations) affects natural ecosystems (the North American forests), we can look at Fig 5. This set of "snapshots" of forest status is obtained by counting forest pollen grains in lake beds and soils. During the past 15,000 years, the ice age conditions gave way to our present interglacial period of warmth. This transition represented some 5°C *global* warming, with 10-20°C warming locally near ice sheets. The boreal forests of Canada were hugging the rim of the great Laurentide glacier in the U.S. Northeast some 10,000 years ago, while presently abundant hardwood species were clinging to small refuges largely in the South. The natural rates of forest movement that can be inferred from the end of the Ice Age is some one km movement per year, in response to temperature changes averaging some 1-2°C per thousand years. If climate were to change much more rapidly than this, then the forests would likely not be in equilibrium with the climate - ie, they could not keep up with the fast change and would go through a period of transient adjustment in which many hard-to-predict changes in species distribution or productivity would very likely occur.

Furthermore, since the slow removal of CO_2 from the atmosphere is largely accomplished through chemical processes in the oceans which take decades to centuries, the rates at which climate change modifies mixing processes in the ocean also needs to be taken into account. There is considerable uncertainty about just how much newly-injected CO_2 will remain in the air over the next century, but most present estimates put this so-called "airborne fraction" at about 50%. However, recent suggestions are encouraging in that they suggest (Firor, 1988) that reducing CO_2 emissions could initially provide a bonus by reducing the airborne fraction whereas increasing CO_2 emissions could increase the airborne fraction thus exacerbating the greenhouse effect. Despite all this uncertainty, most projections of CO_2 concentration continue to suggest a doubling sometime between 2030 and 2080.

Global Climatic Response. Once we have projected how much CO_2 (and other trace greenhouse gases) may be in the air over the next century or so, we have to estimate what its climatic meaning is. The greenhouse effect, despite all the controversy that surrounds the term, is really not at all a scientifically controversial subject. In fact, it is one of the best, most well established scientific theories in the atmospheric sciences! For example, with its very, very dense carbon dioxide atmosphere, Venus has ovenlike temperatures at its surface. Mars, with its very thin carbon dioxide atmosphere has temperatures comparable to our polar winters. The explanation of the Venus hothouse and the Martian deepfreeze has long been quite clear and straight forward: the greenhouse effect. The greenhouse effect works because some gases and particles in an atmosphere preferentially allow sunlight to filter through to the surface of the planet relative to the amount of radiant energy that the atmosphere allows to escape back up through the atmosphere to space. This latter kind of energy, so-called terrestrial infra-red energy, is affected by the amount of "greenhouse" material in the atmosphere (see Fig. 6). Therefore, increase the amount of greenhouse gases, and you increase the planets' surface temperature by increasing the amount of heat that is trapped in the lowest part of the atmosphere. While that part is not controversial, what is controversial is exactly how much earth's surface temperature will rise given a certain increase in a trace greenhouse gas such as CO_2. Complications arise due to processes known as feedback mechanisms. For example, if the warming due to added CO_2 were to cause a temperature increase on Earth, the warming would likely melt some of the snow and ice that now exists. Thus, the white surface covered by the melted snow and ice would be replaced with darker blue ocean or brown soil: surface conditions which would absorb more sunlight than the previous white snow or ice. Thus, the initial warming would create a darker planet which would absorb more energy thereby creating a larger final warming. However, this is only one of a number of possible feedback mechanisms. Clouds can change in amount or brightness, for example, substantially altering the climatic response to CO_2. And because many feedback processes are interacting simultaneously in the climatic system, it is extremely difficult to estimate quantitatively precisely how many degrees warming the climate will undergo, although there is virtually no debate that continued increases of CO_2 will cause global warming.

Unfortunately, there is no time over Earth history that we can turn to when the CO_2 amounts in the atmosphere were, say, twice what they are now, and at the same time examine instruments that tell us what the Earth's climate was then. Therefore, we cannot directly verify our quantitative predictions of greenhouse warming on the basis of purely historical events. Instead, we must base our estimates on natural analogs of large climatic changes and climatic models. These are not laboratory models, since no physical experiments could remotely approach the complexity of the real world. Instead we try to simulate the present Earth climate by building mathematical models, in which the known basic physical laws are applied to the atmosphere, oceans and glaciers, and the equations that represent these laws solved in the best computers available. Then, we simply change in the computer program the effective amount of greenhouse gases, repeat our calculation, and compare it to the so-called "control" calculation for the present Earth. Many such models have been built over the past few decades and are in rough agreement that if CO_2 were to double, then the Earth's surface temperature would eventually warm up somewhere between one and five degrees Celsius, with most recent estimates in the 3.5 to 4.5°C range. Just for a point of comparison, the world average surface temperature difference between our present climate and the Ice Age extreme of 18,000 years ago is such that the Ice Age was "only" about five degrees Celsius colder than now. Thus, temperature change of more than a degree or two globally really is a very substantial alteration. A global increase of more than 2°C above present is unprecedented in the era of human civilization.

Regional Climatic Response. To estimate the societal importance of climatic changes, however, it is not so much global average temperature we need to study but what will be the regional distribution of evolving patterns of climatic change. Will it be drier in Iowa in 2010, too hot in India, wetter in Africa, more humid in New York, more forest fire prone in California or flooded in Venice? Unfortunately, to predict reliably the time sequence of local to regional responses of variables such as temperature and rainfall requires climatic models of greater complexity and expense than are currently available. It's not that we haven't made preliminary calculations of these variables. Rather, to be honest, it would be hard to get a consensus of knowledgeable atmospheric scientists to agree that the regional predictions of state-of-the-art models are very reliable. Nevertheless, there is considerable evidence that the following coherent regional features might well emerge over the next fifty or so years:

- wetter sub-tropical monsoonal rain belts
- longer growing seasons in high latitudes
- wetter springtimes in high and mid latitudes
- drier mid-summer conditions (see Fig. 7 for some mid-latitude areas -- a potentially serious problem for the future agriculture and water supply in major grain producing nations)
- increased probability of extreme (see Table 1) heat waves (with possible health consequences for people and animals in already warm climates) and concomitant reduced probability of extreme cold snaps
- increased likelihood of summertime vegetation fires in drier/hotter regions
- increased sea levels by as much as a few feet over the next hundred years

It must be stressed again that considerable uncertainty remains over the precise probability that these predicted regional features will occur, even though many such plausible scenarios have been investigated. The principal reasons for the uncertainty are two-fold: the crude treatment in climatic models of hydrological processes and the usual neglect of the effects of the deep oceans. The latter would respond slowly -- over many decades to centuries--to climatic warming at the surface, but would also act differentially (that is, non-uniformly in space and over time). That means that the oceans, like the forests, would be out of equilibrium with the atmosphere if greenhouse gases increase as rapidly as typically is projected and if climatic warming were to occur as fast as 2-6°C over the next century. This typical projection, recall, is ten to sixty times faster than the natural average rate of change of temperature seen from the end of the last ice age to the present warm period (i.e., 2-6 °C warming in a century from human activities compared to an average natural warming of 1-2°C per millennium from the waning of the ice age to the middle of the present interglacial epoch). Furthermore, if the oceans are out of equilibrium with the atmosphere, then it will be hard to assign much credibility to specific regional forecasts like that of Fig. 7 until fully coupled atmosphere/ocean models are tested and applied. This is a formidable scientific and computational task.

Validation of Climatic Model Forecasts. Of course, it is appropriate to ask how climatic models' predictions of unprecedented climatic change beyond the next several decades might be verified. Can we make trillion dollar decisions about global economic developments based on the projections of these admittedly dirty crystal balls? The most perplexing question about climate models is whether they can be trusted to provide grounds for altering social policies, such as those governing carbon dioxide emissions. How can models so fraught with uncertainties be verified? There are actually several methods. Although none alone is sufficient, they can together provide significant, albeit circumstantial, evidence of a model's credibility.

The first verification method is checking the model's ability to simulate today's climate. The seasonal cycle is one critical test because these natural temperature changes are several times larger, on a hemispheric average, than the change from an ice age to an interglacial period or a projected greenhouse warming. Global climate models map the seasonal cycle well (see Fig. 8), which suggests they are on the right track. The seasonal test, however, does not indicate how well a model simulates such slow processes as changes in deep ocean circulation or ice cover, which may have an important effect on the decade to century time scales over which CO_2 is expected to double.

A second verification technique is isolating individual physical components of the model, such as its parameterizations, and testing them against reality. For example, one can check whether the model's parameterized cloudiness matches the observed cloudiness of a particular box. But this technique cannot guarantee that the complex interactions of many individual model components are properly treated. The model may be good at predicting average cloudiness but bad at representing cloud feedback. In that case, simulation of overall climatic response to, say, increased carbon dioxide is likely to be inaccurate. A model should reproduce to better than, say, 25 percent accuracy the flow of thermal energy between the atmosphere, surface, and space (see Figure 6). Together, these energy flows comprise the well established greenhouse effect on earth and constitute a formidable and necessary test for all models. A model's performance in simulating these energy flows is an example of physical verification of model components.

A third method for determining overall, long-term simulation skill is the model's ability to reproduce the diverse climates of the ancient earth or even of other planets. Paleoclimatic simulations of the Mesozoic Era, glacial/interglacial cycles, or other extreme past climates help in understanding the coevolution of the earth's climate with living things. As verifications of climate models, however, they are also crucial to estimating both the climatic and biological future (see Schneider, 1987).

Overall validation of climatic models thus depends on constant appraisal and reappraisal of performance in the above categories. Also important are a model's response to such century-long forcings as the 25 percent increase in carbon dioxide and other trace greenhouse gases since the Industrial Revolution. Indeed, most climatic models predict that a warming of some 1°C should have occurred during the past century. The precise "forecast" of the past 100 years also depends upon how the model accounts for such factors as changes in the solar constant or volcanic dust. Indeed, the typical prediction of a degree C warming is broadly consistent but somewhat larger than observed (see Fig. 2). Possible explanations for the discrepancy include: (a) the sensitivity of state-of-the-art models to trace gas greenhouse increases have been overestimated up to two-fold; (b) modelers have not properly accounted for such competitive external forcings as volcanic dust or changes in solar energy output; (c) modelers have not accounted for other external forcings such as regional tropospheric aerosols from agricultural and industrial activity; (d) modelers have not properly accounted for the large heat capacity of the oceans taking up some of the heating of the greenhouse effect and delaying -- but not ultimately reducing --warming of the atmosphere; (e) both present models and observed climatic trends could be correct, but models are typically run for equivalent doubling of carbon dioxide whereas the world has only experienced a quarter of this increase and nonlinear processes have been properly modeled and produced a sensitivity appropriate for doubling but not for 25 percent increase; and (f) the incomplete and inhomogeneous network of thermometers has underestimated actual global warming this century.

Despite this litany of excuses why observed global temperature trends in the past century and those anticipated by most GCMs disagree somewhat, the less than two-fold discrepancy is still remarkably small. Most climatologists do not yet proclaim the observed temperature records to have been caused beyond doubt by the greenhouse effect. It is possible that the close correlation between the observed trend and the predicted warming could still be chance occurrences of the climate dice. One cannot entirely rule out that other factors, such as solar constant variations or volcanic dust, simply have not been adequately accounted for over the past century -- except during the past decade when adequate instruments have been measuring them. Nevertheless, as mentioned, this empirical test of model predictions against a century of observations certainly is consistent to a rough factor of 2. This test is reinforced by the good simulation by most climatic models of the seasonal cycle, diverse ancient paleoclimates, hot conditions on Venus, cold conditions on Mars (both well simulated), and the present distribution of climates on earth. When taken together, these verifications provide strong circumstantial evidence that the current modeling of the sensitivity of global surface temperature to increases in greenhouse gases is probably valid within a factor of two. Another decade or two of observations of trends in earth's climate, of course, should produce signal-to-noise ratios sufficiently obvious that almost all scientists will agree whether present estimates of climatic sensitivity to increasing trace gases have been predicted well or not. That, however, is not a risk-free enterprise.

Environmental Impact of CO_2 Scenarios. Given a set of scenarios for regional climatic change we must next estimate the impacts on the environment and society. Most studies focus on the direct effects of CO_2 and climate change on crop yields and water supplies. Also of concern is the potential for altering the range or numbers of pests that affect plants, or diseases that threaten animals or human health. Also of interest are the effects on unmanaged ecosystems, principally forests. For example, there is major concern among ecologists that the destruction rate of tropical forests due to human expansion is eroding the genetic diversity of the planet. That is, since the tropical forests are in a sense major banks for the bulk of living genetic materials on Earth, the world is losing some of its irreplaceable biological resources through rapid development. The connection of this already formidable environmental problem to climatic change becomes clear when one recognizes that substantial future changes to tropical rainfall have been suggested by climatic models, which means that presently set aside reserves (or refugia) designed as minimal solutions to preserve some genetic resources into the future may not even be as effective as presently planned. That is, if rapidly evolving climatic change will cause conditions in these refugia sufficiently different from the present, then they may not sustain even those species that they are designed to protect.

Sea level rises of 1-4 feet are typically projected for the next 50-100 years, and have major implications for coastal settlements, estuarine ecosystems and the quality of coastal fresh water resources. They are potentially very major impacts of global warming.

Economic, Social, and Political Impacts. The estimation of the distribution of economic "winners and losers", given a scenario of climatic change, involves more than simply looking at the total dollars lost and gained--were it possible somehow to make such a calculation credibly! It also requires looking at these important equity questions: "who wins and who loses?" and "how the might the losers be compensated and the winners taxed?" For example, if the cornbelt in the United States were to "move" north by several hundred miles from a warming, then a billion dollars a year lost in Iowa farms could well eventually become Minnesota's billion dollar gain. Although some macroeconomists viewing this hypothetical problem from the perspective of the United

States as a whole might see no net losses here, considerable social consternation would be generated by such a shift in climatic resources, particularly since the cause was economic activities (ie, CO_2 producing) that directed differential costs and benefits to various groups. Moreover, even the perception that the economic activities of one nation could create climatic changes that would be detrimental to another has the potential for disrupting international relations--as is already occurring in the acid rain case. In essence, what greenhouse gas-induced environmental changes create is an issue I like to call the problem of "redistributive justice."

If a soil moisture decrease such as projected for the US in Fig. 7 were to occur, then it would have disturbing implications for agriculture in the US plains. Clearly, present farming practices and cropping patterns would have to change. The more rapidly the climate changed and the less credibly the changes were predicted (which go together), the more likely it is that the changes would be calamitous. It has been suggested that a future with soil moisture change like Fig. 7 would translate to a loss of comparative advantage of US agricultural products on the world market. Such a scenario would have profound economic and security implications.

Policy Responses. The last stage in diagnosing the greenhouse effect concerns the question of appropriate policy responses. Three classes of actions could be considered. First, is mitigation: purposeful interventions in the environment to minimize the potential effects (for example, deliberately spreading dust in the stratosphere to reflect some extra sunlight to cool the climate as a counter-measure to the inadvertent CO_2 warming). This "solution" suffers from the immediate and obvious flaw that if there is admitted uncertainty associated with predicting the inadvertent consequences of human activities, then likewise substantial uncertainty surrounds any deliberate climatic modification. Thus, it is quite possible that the inadvertent change might be overestimated by our computer models and the advertent change underestimated, in which case our intervention would be "cure worse than the disease" (e.g., see Schneider and Mesirow, 1976). The prospect for international tensions resulting from any deliberate environmental modifications is so staggering, and our legal instruments to deal with this so immature, that it is hard to imagine acceptance of any substantial climate countermeasure strategies for the foreseeable future -- particularly, since there are other more viable alternatives.

The second kind of policy action, one that tends to be favored by most economists, is adaptation (e.g., Schelling, 1983). Adaptive strategies simply say let society adjust to environmental changes without attempting to mitigate or prevent the changes in advance. We could adapt to climate change for example, by planting alternative crop strains that would be more widely adapted to a whole range of plausible climatic futures. Of course, if we don't know what is coming or we haven't developed or tested the seeds yet, we may very well suffer substantial losses during the transition to the new climate. But such adaptations are often recommended because of the uncertain nature of the specific redistributive character of future climatic change.

Finally, the most active policy category is prevention, which could take the form of sulfur scrubbers in the case of acid rain, abandonment of the use of chlorofluorocarbons and other potential ozone-reducing gases, reduction in the amount of fossil fuel used around the world or fossil fuel switching from more CO_2 and SO_2 producing coal to cleaner, more efficient methane. Prevention policies, often advocated by environmentalists, are controversial because they involve, in some cases, substantial immediate investments as a hedge against large future environmental change, change which honestly must be admitted cannot be precisely predicted. The sorts of preventive policies that I believe should be considered are increasing the efficiency of energy end use, the development of alternative energy systems that are not fossil fuel based, or, in the most far-reaching proposal I've seen: a "law of the air". This was proposed in 1976 by the late anthropologist Margaret Mead and the climatologist William Kellogg. They suggested that various nations would be assigned polluting rights to keep CO_2 emissions below some agreed global standard.

A SCIENTIFIC CONSENSUS?

In summary, it is safe to conclude that a strong consensus of knowledgeable atmospheric scientists agrees that reduction of stratospheric ozone, increases in the deposition of acids on Earth and a warming of the climate through the expansion of the greenhouse effect are highly plausible future conditions if current technological, economic and demographic trends continue. The consensus would probably hold that very rapid climatic changes will cause both ecological and physical systems to go out of equilibrium -- a transient condition that makes detailed predictions tenuous. However, most scientists would agree that the faster the changes take place the less we or natural ecosystems will be able to adapt to them without serious disruptions. Both the rate and magnitude of typical projections up to 2050 suggest climatic changes beyond that experienced by civilization could occur. Quite simply, the faster the climate is forced to change, the more likely there will be unexpected surprises lurking. The consensus about global change begins to weaken over detailed assessments of the precise timing and geographic distribution of potential effects, and begins to crumble over the value question of whether present information is sufficient to generate a societal response stronger than more scientific research on the problems-- appropriate (but self-serving) advice which we scientists, myself included, somehow always manage to recommend.

What the public needs, of course, is not to be paralyzed by uncertainty and the confusing, continuing debate among scientists, but to know what questions to ask experts. Here is my recommended list: (1) what can happen? (2) what are the probabilities of alternative outcomes you foresee? (3) how did you determine these odds? (4) what are the potential consequences should those outcomes occur? (5) what possible actions could mitigate those consequences or help us to prevent them or even to take advantage of them? (6) how much will it cost if we take various actions -- or we don't? and (7), whom might it cost if we take various actions -- or we don't? These kinds of questions are generic to any complex technical problem with environmental, social, and political implications.

HIGH LEVERAGE ACTIONS TO COPE WITH GLOBAL WARMING

Clearly, society does not have the resources to hedge against all possible negative future outcomes. Is there, then, some simple principle that can help us choose which actions to spend our resources on? One guideline is called the "tie-in strategy" (e.g., see Schneider and Londer, 1984). Quite simply, let us take those actions which provide widely agreed societal benefits even if the predicted change did not materialize. For instance, one of the principal ways to slow down the rate at which the greenhouse effect will be enhanced is to invest in the efficient use of energy. More efficiency, therefore, would reduce the growing disequilibrium among physical, biological, and social systems and could buy us time both to study the seriousness of the greenhouse effect further and ensure an easier adaptation. However, supposing it turned out that the greenhouse effects now believed to occur prove to be substantial overestimates. What would be wasted by an energy efficiency strategy? First of all, it usually makes good economic sense to conserve energy (although the rate of investment in efficiency does depend, of course, on other competing uses of those financial resources and on the discount rate used). However, it is certain that reduced emissions of fossil fuels -- especially coal -- will reduce acid rain, limit negative health effects in crowded areas from air pollution, and lower dependence on foreign sources of fuel -- especially oil. In addition, more energy efficient factories mean reduced energy costs for manufacturing and thus greater long-term product competitiveness against foreign producers. This will become increasingly true when energy prices rise, perhaps soon, in response to a cutback in oil production. In other words, climatic change is just one of many reasons to consider a policy of strategic energy efficiency. This tie-in or high-leverage strategy therefore suggests a possible priority for policy responses to the advent or prospect of global warming which would yield societal benefits even if present projections turn out to be exaggerations. And if, in the equally likely event, present estimates are too small, then the strategy will have certainly helped to slow down the rate of buildup of greenhouse gases, and slowing down is critical to minimizing transient effects and reducing the likelihood of nasty surprises.

Development of alternative, environmentally safer energy technologies is another example of a tie-in strategy, as is the development and testing of alternative crop strains, trading agreements with nations for food or other climatically dependent strategic commodities and so forth. However, there would be in some circles ideological opposition to such strategies on the grounds that these activities should be pursued by individual investment decisions through a market economy not by collective action using tax revenues or other incentives. In rebuttal, it should be noted that a "market" which does not include the costs of environmental disruptions is not a truly "free" market. Furthermore, it can be pointed out that exactly this kind of strategic investment is made routinely on non-economic (i.e., cost-benefit analyses are secondary) criteria even by the most conservative people: investments in military security. It is not an economic calculus which dictates investments in a military, but rather a strategic consciousness. Similarly, people purchase insurance as a hedge against plausible problems. I am simply arguing that that strategic consciousness -- widely accepted across the political spectrum -- needs to be extended to other potential threats to our security, including a substantially altered environment occurring at unprecedented rates.

Investment to hedge against potential environmental change can, however, deny resources to other socially worthy goals. And, it is often said, "Won't ten more years of research provide us with the answers?". Indeed, I heard just such an argument from a government official at the outset of my career in the early 1970s, and then again from a Department of Energy official in the early 1980s. We will continue to hear such views repeated over the next ten years, I suspect. They are political value judgments, not scientific opinions. Of course, more research will certainly put policy making on a firmer scientific basis. That is why I favor enhanced research as well as other actions. But it is my opinion that credible details about specific "winners and losers" will not be available before we may have committed ourselves to potentially dangerous, large atmospheric changes. If we choose to wait for more scientific certainty over details before preventive actions are initiated, then this is done at the risk of our having to adapt to a larger, faster occurring dose of greenhouse gases, acid rain, and ozone depletion than if actions were initiated today. In my value system high-leverage actions are long overdue.

THE NATIONAL ENERGY POLICY ACT OF 1988

The proposed "National Energy Policy Act of 1988" is action oriented: it stresses least-cost, environmentally sustainable uses of resources -- thereby affording high economic leverage to actions; it acknowledges great scientific uncertainties and thus calls for expanded interdisciplinary research to help put future decision-making on a firmer factual basis; it recognizes that global warming (like ozone depletion) requires international cooperation to develop and deploy new technologies and to provide poor people in less developed countries with alternatives to stop-gap policies that rapidly destroy forests or rely on highly polluting fuels; and (not least) the Act recognizes the urgent need to control population growth so that increased standards of living can be enjoyed by more people with less ultimate environmental disruption. Because the proposed legislation recognizes the complexity of the problem and the linkages between strategies to limit atmospheric change and those to promote economic development, it is commendably in tune with the nature of the issue. I am very supportive of this unusual breadth evidenced by the many titles of the Act, even though I feel that representatives of many diverse interests should be invited to testify on specific language of various sections of the Act. Of course, the comprehensiveness of the Act may perplex some not aware of the many facets of the global warming issue, but unless the broad nature of the problem is recognized and met with a comparably broad set of solutions, we will diminish our ability to control the future, and increase the likelihood of being victims of our own short-sightedness.

It is a cliche that "not to decide is to decide." The National Energy Policy Act of 1988 tries to confront directly the multifaceted elements of atmospheric change; it recognizes that unprecedented changes are plausible and that high-leverage actions can be implemented now; it does not use platitudes about scientific uncertainty to evade the need to act now. This proposed legislation is a good initial platform from which to build the national and international responses needed to help us cope with the rapidly changing atmosphere. It is often said that we do not so much inherit the world from our forebears, but rather we borrow it from our children. It is increasingly urgent that we act to prevent our debt from growing out of control.

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FIGURE CAPTIONS

Fig. 1. Surface air temperature trends for the eight latitude zones. (Source: Hansen and Lebedeff, *J. Geophys. Res. 92*, 13,345-13,372, 1987)

Fig. 2. Comparison of Hansen and Lebedeff (1987) annual global and hemispheric temperature trends with those reported by Jones *et al.* (1986). (Source: Hansen and Lebedeff 1987)

Fig. 3. Drought severity index estimated as of July 9, 1988. This is as intense a drought map as the US has experienced since the 1930s.

Fig. 4. Various CO_2 scenarios based on specified sets of annual energy growth rate assumptions. (Source: Lovins *et al.*, *Least-Cost Energy: Solving the CO_2 Problem*, Brick House, Andover, 1981)

Fig. 5. The relative fraction (in percent) of fossil pollen from various species of trees is shown on the maps. These pollen patterns can be correlated to climatic conditions. These maps show, for example, that at the end of the last (Pleistocene) Ice Age 11,000 years ago much of the northeastern United States was covered with spruce forests, which are found today in central Canada near Hudson Bay. (Source: Bernabo and Webb III, *Quat. Res. 8*, 64-95, 1977)

Fig. 6. The greenhouse effect is well established. It arises because the earth's atmosphere tends to trap heat near the surface. Carbon dioxide, water vapor and other gases are relatively transparent to the visible and near-infrared wavelengths that carry most of the energy of sunlight, but they absorb more efficiently the longer, infrared wavelengths emitted by the earth. Hence an increase in the atmospheric concentration of greenhouse gases tends to warm the surface. (Source: Schneider, *Scientific American 256*, No. 5, 72-80)

Fig. 7. CO_2-induced change in soil moisture expressed as a percentage of soil moisture obtained from a computer model with doubled CO_2 compared to a control run with normal CO_2 amounts. (Source: Manabe and Wetherald, *Science 232*, 626-628, 1986)

Fig. 8. A three-dimensional climate model has been used to compute the winter to summer temperature extremes all over the globe. The model's performance can be verified against the observed data shown below. This verification exercise shows that the model quite impressively reproduces many of the features of the seasonal cycle. These seasonal temperature differences are mostly larger than those occurring between ice ages and interglacials or for any plausible future carbon dioxide change. (Source: Manabe and Stouffer, *J. Geophys. Res. 85*, 5529-5554, 1980)

Table 1

IF ONLY TEMPERATURE GOES UP BY 3°F, THEN ODDS FOR JULY HEAT WAVES* GO UP:

	ODDS NOW	ODDS IF +3°F
WASHINGTON D.C. (95°F)	17%	47%
DES MOINES (95°F)	6%	21%
DALLAS (100°F)	38%	68%

Source: Mearns, L. O., R. W. Katz, and S. H. Schneider, 1984: Changes in the probabilities of extreme high temperature events with changes in global mean temperature, J. Clim and Applied Meteorl. 23, 1601-1613.

* "Heat wave" means 5 or more days in a row with max temp above 95/100°F. threshold

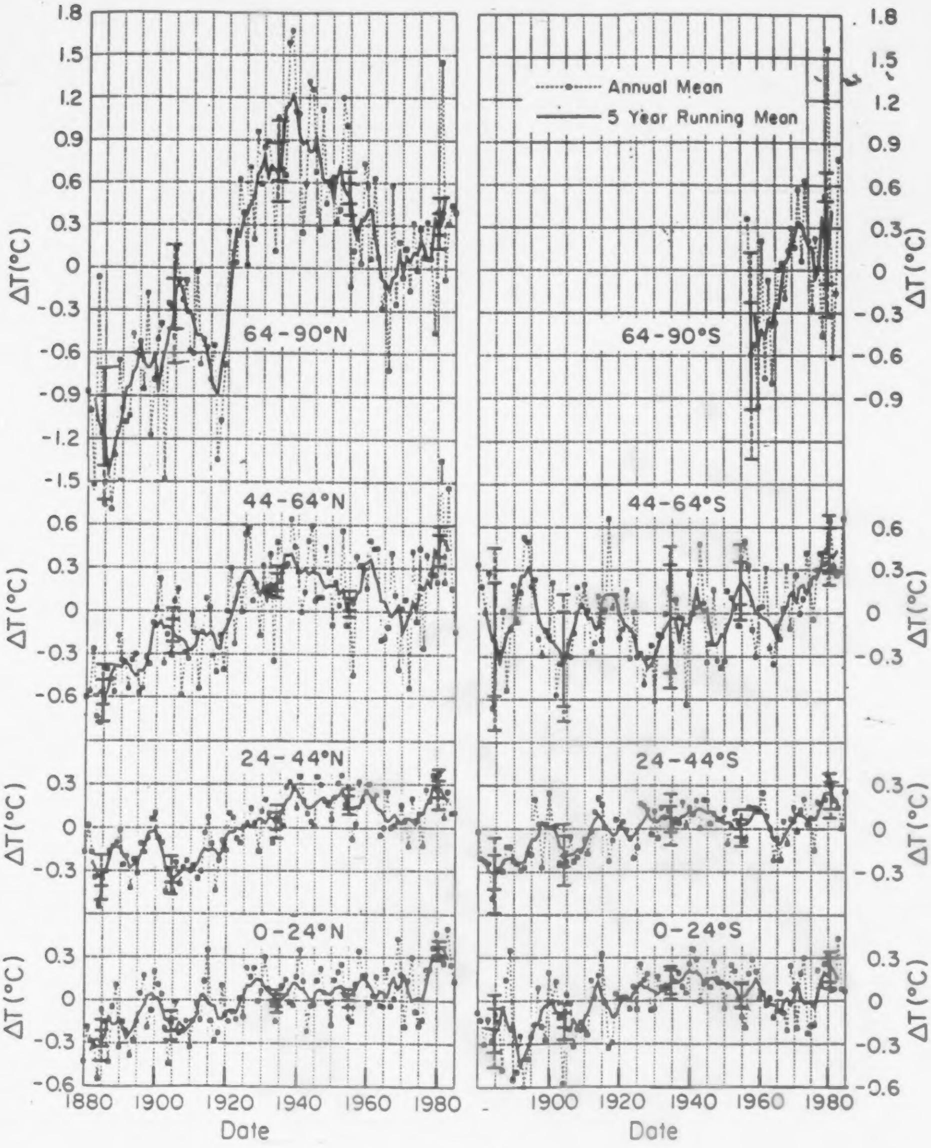

Annual Mean
5 Year Running Mean
64-90°N
64-90°S
44-64°N
44-64°S
24-44°N
24-44°S
0-24°N
0-24°S
ΔT(°C)
1.8
1.5
1.2
0.9
0.6
0.3
0
-0.3
-0.6
-0.9
-1.2
-1.5
1880
1900
1920
1940
1960
1980
Date

Fig. 1

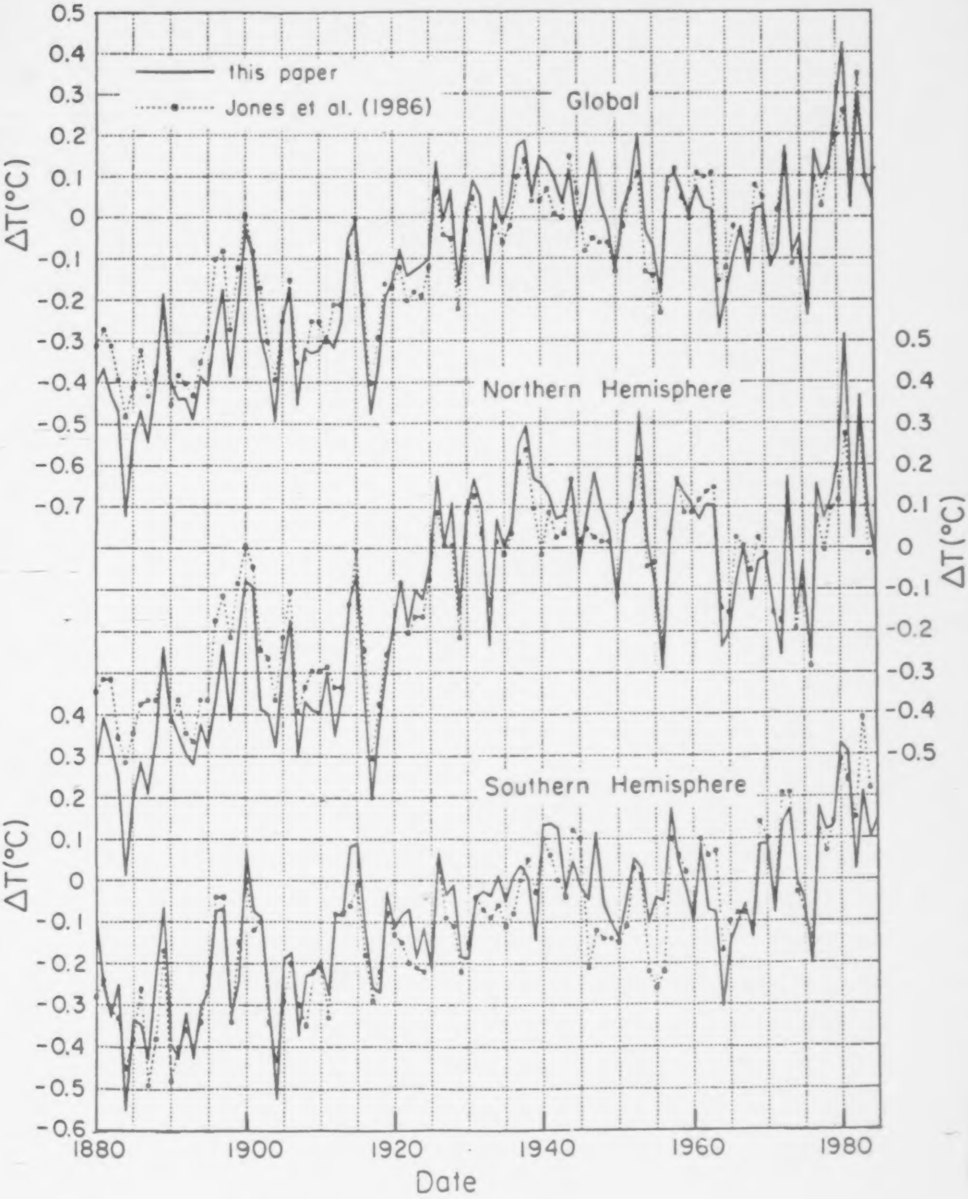
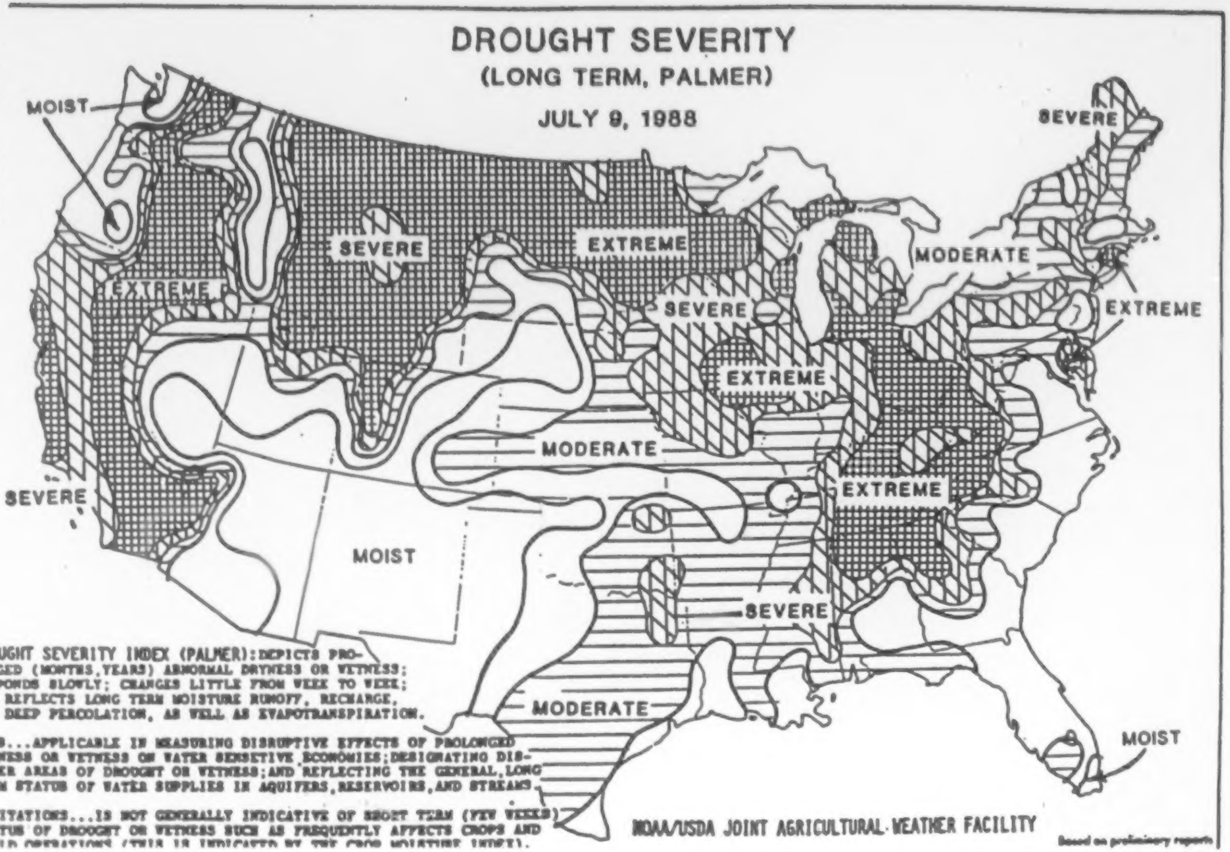

this paper
Jones et al. (1986)
Global
Northern Hemisphere
Southern Hemisphere
ΔT(°C)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
1880
1900
1920
1940
1960
1980
Date

Fig. 2

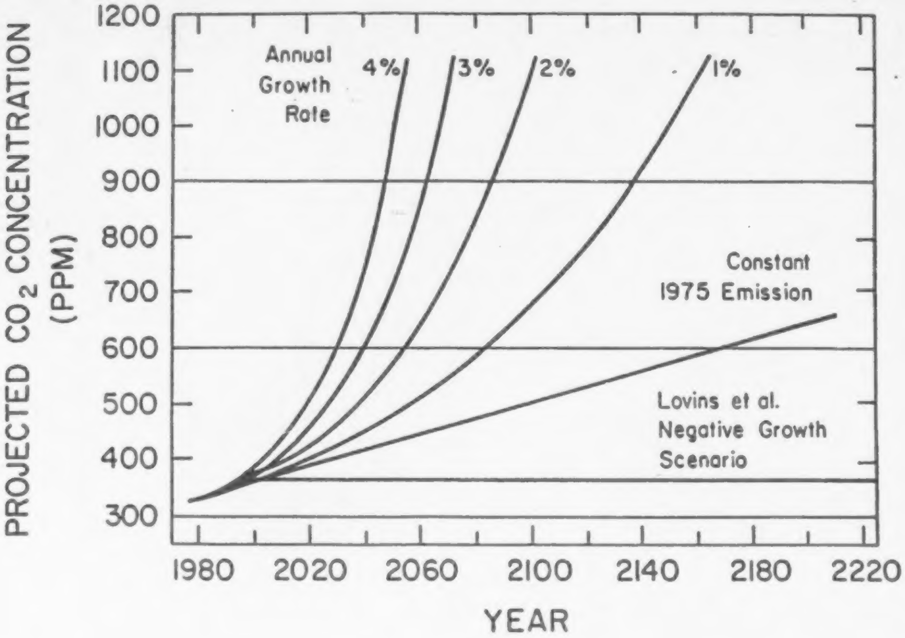

DROUGHT SEVERITY
(LONG TERM, PALMER)
JULY 9, 1988
MOIST
SEVERE
EXTREME
SEVERE
EXTREME
SEVERE
EXTREME
MODERATE
MODERATE
EXTREME
SEVERE
EXTREME
MOIST
SEVERE
MODERATE
MOIST
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY
Based on preliminary reports

DROUGHT SEVERITY INDEX (PALMER): DEPICTS PROLONGED (MONTHS, YEARS) ABNORMAL DRYNESS OR WETNESS; RESPONDS SLOWLY; CHANGES LITTLE FROM WEEK TO WEEK; AND REFLECTS LONG TERM MOISTURE RUNOFF, RECHARGE, AND DEEP PERCOLATION, AS WELL AS EVAPOTRANSPIRATION.

USES...APPLICABLE IN MEASURING DISRUPTIVE EFFECTS OF PROLONGED DRYNESS OR WETNESS ON WATER SENSITIVE ECONOMIES; DESIGNATING DISASTER AREAS OF DROUGHT OR WETNESS; AND REFLECTING THE GENERAL, LONG TERM STATUS OF WATER SUPPLIES IN AQUIFERS, RESERVOIRS, AND STREAMS.

LIMITATIONS...IS NOT GENERALLY INDICATIVE OF SHORT TERM (FEW WEEKS) STATUS OF DROUGHT OR WETNESS SUCH AS FREQUENTLY AFFECTS CROPS AND FIELD OPERATIONS (THIS IS INDICATED BY THE CROP MOISTURE INDEX).

Fig. 3



The extent to which CO_2-induced climatic change will prove significant in the future depends, of course, on the rate of injection of CO_2 into the atmosphere. This depends, in turn, on behavioral assumptions as to how much fossil fuel burning will take place. (This graph neglects biospheric effects.) Since the end of World War II, a world energy growth rate of about 5.3 percent occurred until the mid-1970s, the time of the OPEC price hikes. Rates have come down substantially since then. The figure shows projected CO_2 concentrations for different annual growth rates in fossil energy use, including the assumption that no increase in fossil energy use occurs (constant 1975 emission) and even a "negative growth scenario" in which energy growth after 1985 is assumed to be reduced by a fixed amount [0.2 terra watts (TW), which is about 2 percent of present demand] each year. [Source: A. B. Lovins, L. H. Lovins, F. Krause, and W. Bach, Least-Cost Energy: Solving the CO_2 Problem *(Andover: Brick House), p. 10.]*

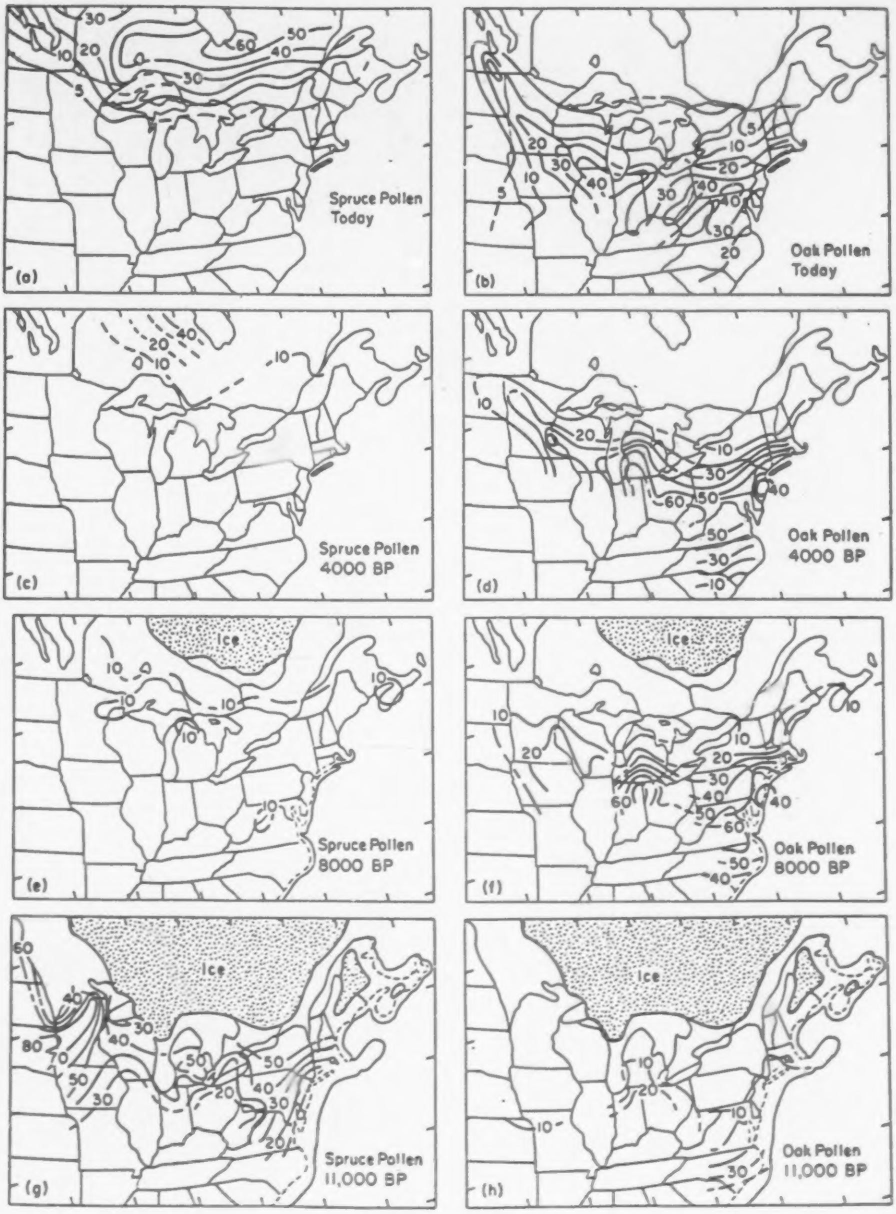
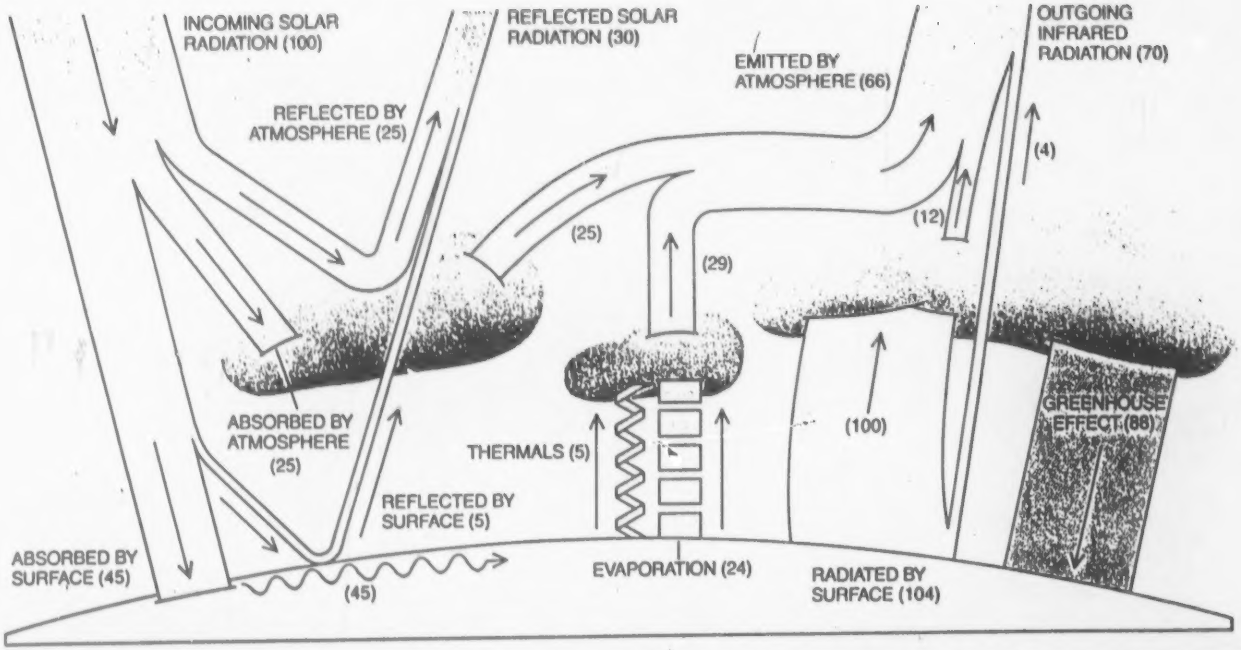

(a)
Spruce Pollen Today
(b)
Oak Pollen Today
(c)
Spruce Pollen 4000 BP
(d)
Oak Pollen 4000 BP
(e)
Spruce Pollen 8000 BP
(f)
Oak Pollen 8000 BP
Ice
(g)
Spruce Pollen 11,000 BP
(h)
Oak Pollen 11,000 BP

Fig. 5

Fig. 6


INCOMING SOLAR RADIATION (100)
REFLECTED SOLAR RADIATION (30)
EMITTED BY ATMOSPHERE (66)
OUTGOING INFRARED RADIATION (70)
REFLECTED BY ATMOSPHERE (25)
(25)
(29)
(12)
(4)
ABSORBED BY ATMOSPHERE (25)
THERMALS (5)
(100)
GREENHOUSE EFFECT (88)
REFLECTED BY SURFACE (5)
ABSORBED BY SURFACE (45)
(45)
EVAPORATION (24)
RADIATED BY SURFACE (104)

GREENHOUSE EFFECT arises because the earth's atmosphere tends to trap heat near the surface. Carbon dioxide, water vapor and other gases are relatively transparent to the visible and near-infrared wavelengths (*blue*) that carry most of the energy of sunlight, but they absorb more efficiently the longer, infrared wavelengths (*red*) emitted by the earth. Most of this energy is radiated back downward (*dark red*). Hence an increase in the atmospheric concentration of greenhouse gases tends to warm the surface.

Senator **Wirth**. Thank you very much, Dr. Schneider.

Since we have been talking about the interdisciplinary nature of what we have to do, certainly one of the great interdisciplinary agencies is the Environmental Protection Agency, and Mr. Robert Wayland is Deputy Assistant Administrator for Policy, Planning and Evaluation. Mr. Wayland, we are very pleased to have you with us today. Thank you very much for coming up. Your statement and that of our other witnesses will, as I noted earlier, be included in full in the record. Why don't you proceed in the way that you think would be most helpful so that we can get on to our other two witnesses and get into a discussion between you and questions and answers. Thank you for being here.

STATEMENT OF ROBERT WAYLAND III, DEPUTY ASSISTANT ADMINISTRATOR FOR POLICY, PLANNING AND EVALUATION, ENVIRONMENTAL PROTECTION AGENCY

Mr. **Wayland**. Thank you very much, Mr. Chairman. I appreciate your inclusion of the full statement in the record. And, therefore, I will try to simply highlight those points that I think are most significant.

EPA's actions have three principal elements: examining the potential effects of climate change on natural systems and infrastructure; improving our understanding about the causes and magnitude of global climate change, which will be central to evaluating the need for and effectiveness of any stabilizing actions that may be available; and international activities to contribute to our own understanding of the issue as well as raise the awareness of other nations on how they may be affected and how their policies affect emissions of greenhouse gases.

The primary mechanisms by which the first two of these three elements is being pursued is through the development of two reports to Congress requested in 1986 and planned for submission late this calendar year. I will return to these in a moment. But first I would like to ask your indulgence as I have a chart displayed which I think will be a useful starting point to review the importance of various greenhouse gases and the sources of their emissions.

I think this first chart illustrates that the gases which contributed to the warming effect through the decade that we have entered made different relative contributions to the problem than we expect to be occurring today. In particular, the growth of CFC use and increases in methane made clear that the problem is one that needs to focus on multiple greenhouse gases. And we need to focus on more than a single source and more than just a group of sources as we consider strategies for responding.

My colleague is going to display a chart which is going to point out that even with CO_2, there are three significant sources, the first of which we have talked about a lot today, fossil fuel combustion, where the United States contributes probably 23 percent of total emissions. Russia and China make major contributions as well. But deforestation, occurring largely in the developing world, Brazil, Indonesia and Colombia, underscore the need to look for international cooperation in dealing with the issue.

Senator WIRTH. Can you do that again? I am sorry. I was interrupted.

Mr. WAYLAND. Certainly. I was trying to simply point out that CO_2 emissions have a number of significant sources, and deforestation is one that is of particular concern and which, of course, is not a major problem in the United States. Developing countries, Brazil, Indonesia and Colombia, make a significant contribution along with other countries as a result of the deforestation.

Senator WIRTH. For the record, of the total amount of CO_2 emissions, 73 percent comes from fossil fuels; 26 percent from deforestation; and 2 percent from cement production. Is that right?

Mr. WAYLAND. Yes, sir.

Senator WIRTH. What that tells us is that any strategy that you have has to focus—I am sure you will be getting to that. Is that right? The international strategy? How do you deal with deforestation? What do you say to the Chinese?

Mr. WAYLAND. That is correct. And deforestation kind of hits you twice because you first have the emissions that are associated with the slash and burn of the clearing, and then you lose the potential for those forests to serve as a major sink of CO_2 where the relative advantage of forests over crop land is probably a 20 to 100-fold improvement in their ability to remove CO_2.

Senator WIRTH. You have a triple problem. You want to say don't slash and burn anymore. Don't cut down the forests. Second, without the forests, you have an increased amount as well. And third, then what do you replace it with economically.

Mr. WAYLAND. That's correct.

Senator WIRTH. With the similar kind of problem with the Chinese, we can say to them you are embarking upon a rapid strategy of industrialization dependent largely on coal and, as I gather, dirty coal as well. And we can't turn around and say to them don't industrialized because coal is a bad thing. We have to develop an alternative, and that gets us to one of the policy questions. What are the alternatives that you provide to Brazil, Indonesia or Colombia for deforestation? What are the alternatives you provide, say, to the Chinese for coal?

Mr. WAYLAND. That is absolutely correct. And I think the next chart that I am going to ask Joel to show you illustrates that in the same respect methane emissions, which are certainly a significant factor in terms of greenhouse emissions, pose similar problems where rice production is a major contributor with 24 percent of the total emissions. Biomass burning, which is a principal, primary fuel source for many less developed countries, and domestic animals all represent very significant contributions. The top three rice producing countries are India, China, and Bangladesh.

I think we want to try to underscore here, as we come to chlorofluorocarbons, indeed, the United States and the developed countries, particularly the European Economic Community, did contribute over half to the total emissions of CFCs. And fortunately, we have undertaken an international solution to that problem. But the problem was a somewhat less difficult problem in that you had essentially a narrow family of uses, sophisticated uses employed by sophisticated countries, that largely needed to be discussed in the international forum.

With this background, I would like to speak briefly about the two reports to Congress that EPA has under preparation. The first of these reports is going to deal with the effects of global climate change, and our intention is to try to develop insights into the ranges of possible future effects that may occur from climate change scenarios. And we want to identify the qualitative sensitivities of different environmental systems and processes to changes in climate and links among potential effects and regions.

As has been mentioned earlier, forecasts of impacts on a regional scale are beyond the capabilities of current science. The existing general circulation models can't be used to make predictions at the regional level. And, therefore, EPA is developing a range of scenarios to use to try to understand what the sensitivities may be. And we have adopted a two-phase approach.

One is to look at regional case studies where we are trying to examine how hyrdogeology, agriculture and forestry and infrastructure may change in four regions of the United States: the southeast because of its unique ecosystems and coastal activity, forestry and agriculture; the Great Lakes because of the largest source of fresh water in the world; California, which is both highly populous and has a great demand for and a scarcity of water; and the Great Plains because of their agricultural productivity.

In addition to the regionalized case studies, we are examining several issues on a nationwide basis, among them sea level rise, an area in which the Environmental Protection Agency has done work for a number of years where we are looking at national impacts on beaches and wetlands, including the inundation of barrier islands.

In energy, we are looking at changes in availability and demand of energy on a national scale to determine what alternative climate scenarios would mean in terms of heating and cooling, energy demand.

We are also looking at air pollution effects, and the changes in air pollution patterns due to warming temperatures. Of course, our headlines have made everybody very much aware that the atmospheric ozone problem has been exacerbated by this summer's very high temperatures.

So, information on the possible effects of climate change is one of several important considerations that should guide the evaluation of response options. Other important considerations include the feasibility cost and effectiveness of emission limiting strategies and the prospects for adaptation approaches. And those are all areas that are dealt with in EPA's stabilizing report which examines policy options in these areas.

I guess to reinforce a point I wanted to make earlier, emissions of trace gases are a multi-sectoral problem. In contrast to stratospheric ozone depletion from CFCs, no single sector can be isolated and held principally responsible for global warming. For example, CO_2 emissions in the United States are distributed among several sectors, electric utilities representing a significant one, transportation, residential and commercial uses and industrial processes. So, our policy options will include examinations of factors involving many sectors of the economy.

Of course, principal among these in the focus of your legislation is energy policies where we are attempting to examine potential improvements in end use energy efficiency. The ratio of energy consumption to GNP growth has already been changed substantially, and there is reason to believe that further improvements are possible. And they can occur in several sectors: residential, commercial, transportation.

The energy efficiency improvements that we have seen have already allowed us to hold energy use constant at the 1973 level while expanding our economy in the meanwhile by 40 percent. Yet, evidence that more is possible is suggested by the fact that Japan and West Germany currently use only half as much energy per unit of output as does the United States.

Electric production is the route to which an increasing amount of energy production is being directed. And increased electricity from fossil fuel power plants will lead to increases in the emissions of CO_2s. And this can particularly be a problem in less developed countries.

We are examining what advanced technologies can realize in terms of boosting efficiencies—technologies under development in the United States and elsewhere.

In the area of emerging technologies, renewables are appealing because they don't emit CO_2. Fossil fuel technologies could eventually be replaced with non-fossil fuel sources of energy such as solar, nuclear and hydroelectric. But there are very key considerations and impediments associated with any fundamental change of that nature, including the proper amount of research and development to advance those technologies, the economics of them and public acceptance. Perhaps available on a shorter term horizon are opportunities to realize improvements through redesigned or more energy efficient technologies such as cogeneration combined cycle technologies.

But beyond the energy sector, our studies will examine agricultural practices to, for example, try to determine what techniques may be available to reduce methane from cattle and rice production. And we are also examining techniques for reducing fertilizer emissions of nitrous oxide.

In the area of deforestation and reforestation, which represents 25 percent of the CO_2 emissions as we saw earlier, the uptake of carbon by vegetation in forests is a particularly important factor. Deforestation is unfortunately occurring at an accelerating in rate the developing countries and is the largest source of biotic emissions of CO_2. If we could halt or reverse that trend, tropical forests could serve as a large carbon sink.

I also think it is important to examine the energy paths of less developed countries and determine what the options are there and what the implications are for global climate.

Finally, I had mentioned earlier the ratification of the Montreal Protocol which EPA and the United States Government are encouraging as a means to severely limit emissions of CFCs that are a contributor to the greenhouse problem.

I hope that this illustrates that at least from my perspective, there are very important international dimensions to the problem. And I think that in addition to preparing the reports that I have referred to earlier, the Environmental Protection Agency and other parts of the U.S. Government are very much involved in the international arena to try to raise the consciousness about these problems and begin a dialog toward global solutions.

The U.S. Government has endorsed the establishment of an international panel on climate change by UNEP and WMO as a process to help ensure an orderly international process of activities following a path similar to those directed by our reports, that is, to assess the state of scientific knowledge on global climate change and examine the social and economic effects from warming and potential responses.

I also want to mention that EPA has bilateral agreements with the Soviet Union and the People's Republic of China, and is working with other countries to further our understanding of climate change issues. A 1972 U.S./USSR agreement on cooperation in the field of environmental protection has as its focus this year the preparation of a joint report on future climates, attempts to begin examining response strategies and measurements of methane concentrations and stratospheric ozone changes in the Arctic and Antarctic regions.

In addition, in 1987 EPA signed an agreement with China which included several provisions on global climate change. And I should mention that Dr. Li Chang-Sheng has joined me at the hearing today. He is spending the next year with the Environmental Protection Agency under this agreement. He will work on projects related to climate change. And in addition, as the other aspects of this agreement provide, the United States will be looking for cooperation from the Chinese in understanding more about the concentrations of trace gases in remote regions, what the emissions from rice fields and other sources are and examining future energy development paths.

I would just like to close by mentioning the science assessment that is under development as a result of the Global Climate Protection Act of 1987, which you alluded to, Mr. Chairman, in your opening remarks. That act requires the Secretary of State and the Administrator of EPA to jointly submit by the end of 1989 a report that analyzes current international scientific understanding of the greenhouse effect, assesses U.S. efforts to gain international cooperation in limiting global climate change, and describes U.S. strategy for seeking further international cooperation. This mandate obviously will require close cooperation among all of the several agencies involved and all of whom have very important contributions to make.

I think I will halt at this point, Mr. Chairman, recognizing the time limits.

[The prepared statement of Mr. Wayland follows:]

TESTIMONY OF
ROBERT WAYLAND, III
DEPUTY ASSISTANT ADMINISTRATOR
FOR POLICY, PLANNING AND EVALUATION
U.S. ENVIRONMENTAL PROTECTION AGENCY
BEFORE THE
ENERGY AND NATURAL RESOURCES COMMITTEE
U.S. SENATE

August 11, 1988

Good morning. I am pleased to be here to discuss the Environmental Protection Agency's Global Climate Change Program and how energy policy can influence the greenhouse effect.

The Issue

Greenhouse gases, such as carbon dioxide, nitrous oxide, methane, and others, occur naturally in the atmosphere. They serve as a figurative thermal blanket, allowing solar radiation to pass through the atmosphere and strike the earth's surface, while absorbing some of the infrared radiation emitted back from the surface. This absorption of radiation warms the atmosphere and gives us our present climate. If there were no greenhouse gases, the earth would be approximately 30°C colder. If the concentrations of greenhouse gases are increased, the atmospheric temperature will increase.

There is scientific consensus that increases in greenhouse gas emissions will result in climate change. Atmospheric concentration of carbon dioxide has increased approximately 25 percent since about 1860, in part due to fossil fuel combustion and industrial and agricultural activities. The National Academy of Sciences' Nirenberg Study Commission has estimated that the effective doubling of the concentration of carbon dioxide in the atmosphere could eventually lead to a global warming of 1.5 to 4.5°C. However, considerable uncertainty exists with regard not only to the timing, but also to the ultimate magnitude of any global warming. In addition, there is great uncertainty about how climate variability and regional climate patterns may change.

Sources of Greenhouse Gases

Since the onset of the industrial revolution, man's activities have added to the concentrations of greenhouse gases. Burning of fossil fuels, deforestation, expanded agriculture, and, more recently, the use of synthetically produced chlorofluorocarbons (CFCs) have all contributed to this increase (see EXHIBITS 1A and 1B). Greenhouse gases are emitted from both the developed and less developed countries. Approximately seventy-five percent of CO_2 emissions from anthropogenic sources come from the burning of fossil fuels, and twenty-three percent result from deforestation -- largely in tropical countries (see EXHIBIT 2). Western Europe and North America account for approximately forty percent of fossil fuel emissions, but since the early 1970s, their emissions have remained relatively stable. In fact, the United States fraction has been decreasing. The Soviet Union and Eastern Europe, the People's Republic of China, the Pacific rim countries and the developing countries contribute

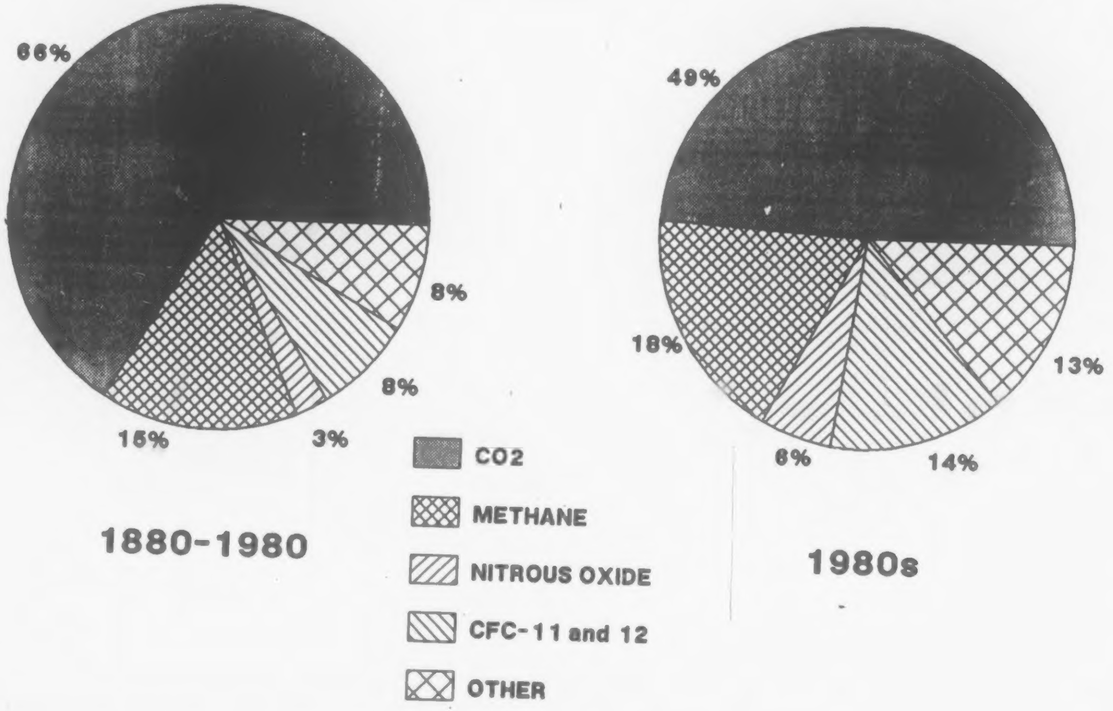
EXHIBIT 1A

EXAMPLES OF IMPORTANT TRACE GAS SOURCES

Trace Gas	Sources
Carbon Dioxide (CO_2)	Combustion/Deforestation
Chlorofluorocarbons (CFCs)	Refrigerants/Packaging/Solvents/Other
Methane (CH_4)	Rice/Wetlands/Livestock/Tundra/Landfills
Nitrous Oxide (N_2O)	Combustion/Soils/Fertilizers
Nitrogen Oxides (NO_X)	Airplanes/Stationary Combustion/ Transportation
Carbon Monoxide (CO)	Transportation/Biogenic/Other Combustion

EXHIBIT 18

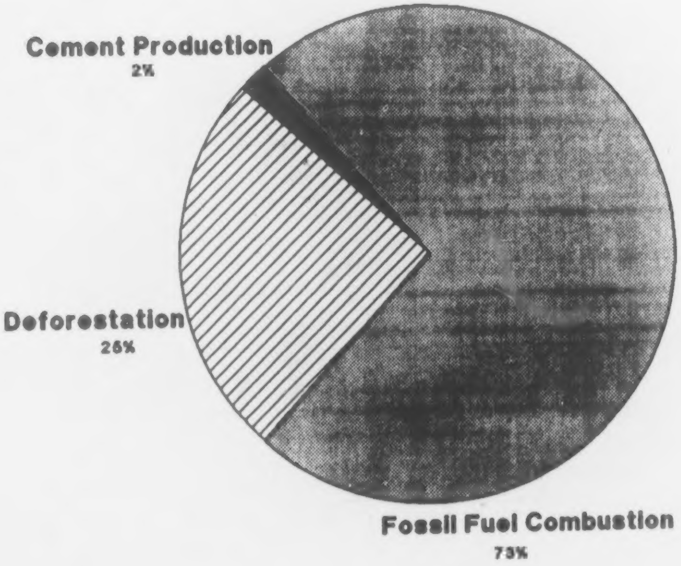
GREENHOUSE GAS CONTRIBUTIONS TO GLOBAL WARMING



Sources: 1880-1980: Ramanathan et al., 1985; 1980s: Hansen et al.

EXHIBIT 2

CURRENT EMISSIONS OF CO2 BY SOURCE



TOP THREE SOURCES

Fossil Fuel Combustion

1. United States
2. USSR
3. China

Cement Production

1. China
2. USSR
3. Japan

Deforestation

1. Brazil
2. Indonesia
3. Colombia

Sources: Rotty, 1987; Houghton, et al, 1987.

approximately sixty percent of fossil fuel emissions, but most importantly, their share is rising (see EXHIBIT 3). With regard to other gases, approximately seventy-five percent of the CFCs are produced in North America and Europe, while major sources of methane are associated with rice production in Asia (see EXHIBITS 4A and 4B). Thus, all countries contribute to greenhouse gas emissions and share some responsibility for their continued growth.

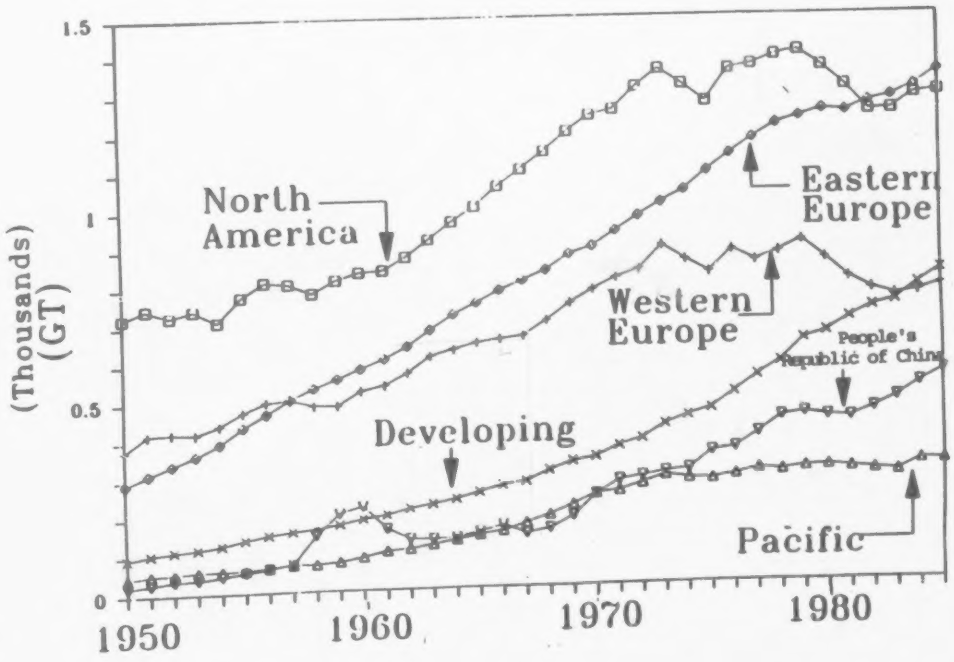
EPA's Interest

EPA is involved in the global climate change issue for a number of reasons. First, EPA has traditionally examined the effects of pollution on human health and the environment and options to reduce emissions of those pollutants. For example, under the Clean Air Act, we study the emissions, transport, exposure, and ultimate effects of air pollutants. We also examine technological options to limit emissions and when necessary, regulate these emissions to protect the environment.

Second, EPA has experience in dealing with global environmental issues. For example, EPA played a leading role in analyzing the effects of stratospheric ozone depletion and in developing options to limit emissions of such ozone depleting chemicals as CFCs and halons. With U.S. domestic policy under the Clean Air Act and international policy proceeding in parallel, international action eventually led to the adoption of

EXHIBIT 3

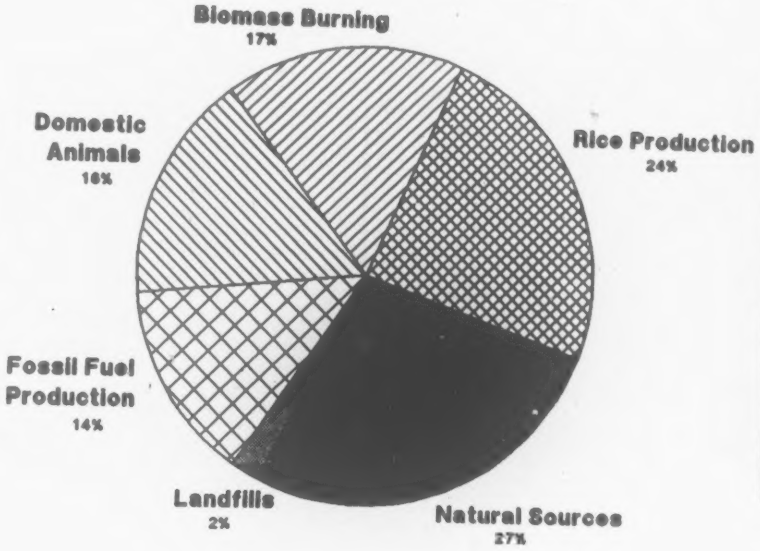
ANNUAL FOSSIL FUEL CO2 EMISSIONS BY WORLD REGIONS
1950 – 1985



Rotty, Personal communication. 1987

EXHIBIT 4A

CURRENT EMISSIONS OF METHANE BY SOURCE



TOP THREE PRODUCERS

Rice Production

1. India
2. China
3. Bangladesh

Domestic Animals

1. India
2. USSR
3. Brazil

Fossil Fuel Production

1. United States
2. USSR
3. China

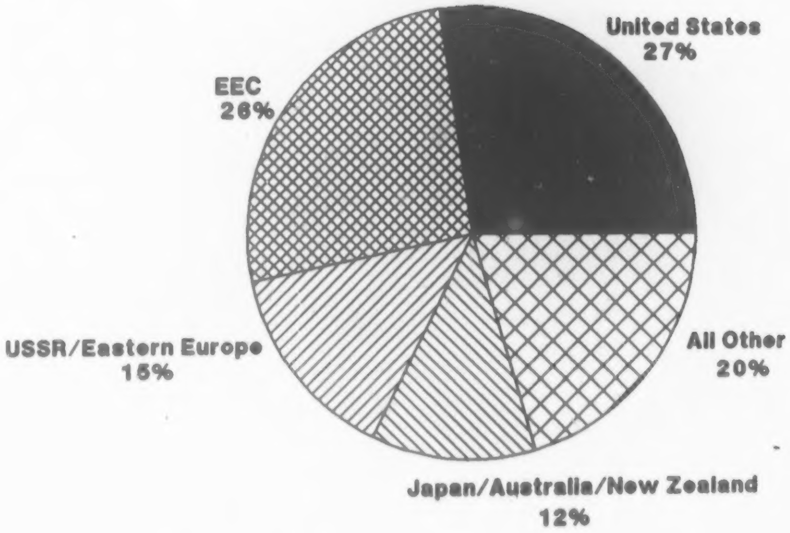
Sources: Bolle et al, 1986; Matthews & Fung, 1987;

Crutzen et al, 1986; Hozapfel-Pschorn and Seiler, 1986;

Seiler & Conrad, 1987; Lerner et al, 1988.

EXHIBIT 4B

GLOBAL PRODUCTION OF CFCs



Source: Chemical Manufacturers Association, 1986;
United States EPA, 1988.

an unprecedented global environmental agreement, the Montreal Protocol on Substances that Deplete the Ozone Layer.

Although the Agency has studied the effects of global warming for several years, its current efforts on global climate change have been stimulated by two Congressional actions. The first is a Congressional request made in 1986 to develop two reports on global warming. The request stated that a report on policy options for stabilizing greenhouse gas emissions should be prepared and should examine options to reduce emissions of a number of greenhouse gases from energy use, CFC production, deforestation, and other activities. The request also asked EPA to prepare a report on the health and environmental effects of climate change, examining such issues as agriculture, forests and water resources. This study is focusing on four regions of the country, the Southeast, the Great Lakes, the southern Great Plains, and California. Results of our analyses are not yet available, but we are committed to delivering both reports to Congress by the end of this year.

In response to the Congressional Directive, EPA is actively working on a report that assesses the effects of global climate change on forests, lakes, wetlands, agriculture, human health, and other aspects of the environment. The focus of the Effects Report will be on the United States. The Report will examine how hydrology, agriculture, forestry and infrastructure may change in four regions of the United States: the Southeast, the Great Lakes, California, and the Great Plains. These regions were chosen because of unique characteristics that each exhibits. The Southeast has unique ecosystems and much coastal activity, forestry, and agriculture. The Great Lakes are the largest source of fresh water in the world. California is a highly populated area with a high demand for, and a limited supply of, water. The Great Plains are among the most productive agricultural areas in the world.

Another goal of our effort will be to use the best available models, atmospheric scientists, and researchers to assess the effects of climate change. Yet, we recognize that precise quantitative forecasts of impacts are beyond the capabilities of current science. The existing general circulation models cannot be used to make precise predictions--especially at the regional level. We are therefore looking at a range of potential impacts (i.e., scenarios) in order to provide a sense of the sensitivities of different effects to changes in temperature and other variables. These scenarios will not necessarily bracket the entire range of potential impacts.

The Effects Report will attempt to achieve several goals. Despite the scientific uncertainties in the state of the art, we hope to be able to outline the insights we identify into the ranges of possible future effects that may occur under climate change scenarios, as well as establish any qualitative sensitivities of different environmental systems and processes to changes in climate. We will also describe any qualitative linkages between the effects observed in different regions mentioned above. EPA has actively encouraged participation of other federal agencies and the broader scientific community in the research process leading up to these reports.

For example, EPA has organized four workshops this spring to present preliminary analyses and to gather information from experts on the link between greenhouse gas emissions and agriculture, electric utilities, developing countries, and energy efficiency. We believe the results of these workshops will assist the Federal government in identifying relevant research needs.

The second Congressional action is the Global Climate Protection Act of 1987. Included in its provisions is the requirement that,

> The President, through the Environmental Protection Agency, shall be responsible for developing and proposing to Congress a coordinated national policy on global climate change.

The Act also provides for the Secretary of State to seek further international cooperation on limiting global climate change. In addition, the Act requires that the Secretary of State and the Administrator jointly submit, by the end of 1989, a report analyzing current international scientific understanding of the greenhouse effect; assessing U.S. efforts to gain international cooperation in limiting global climate change; and describing a U.S. strategy for seeking further international cooperation to limit global climate change. This is a very broad mandate which will require close cooperation with other agencies (including

NASA, NOAA, COE, and the Departments of Energy, Agriculture, Interior), the National Climate Program Office, and the Domestic Policy Council. The Act encourages coordination of domestic and international climate activities with research and impact analyses that are consistent with policy goals.

Our Office of Research and Development, in addition to supporting the Agency effort to respond to Congress' request for these two reports, is also responding to a request from the Administrator to improve its institutional capabilities to begin work in the global climate change arena. We are preparing a comprehensive inter-agency plan that will define more clearly the Agency's research role in developing better emissions factors, identify the ecosystems that are sensitive to climatic variation and may be at risk, and establish possible relationships between global and regional changes. A plan for EPA's research efforts will enable us to interact effectively with existing efforts in other Federal agencies and with scientific research and assessment activities in domestic and international forums. ORD is an active participant in OSTP's Committee on Earth Sciences, the group coordinating the Federal Global Change research effort.

EPA's International Activities

Let me turn to the subject of EPA's role in international activities, because no single country alone will be able to decisively affect the global CO_2 problem.

Several international "actors" are currently involved in the global climate change arena. The United Nations Environment Programme (UNEP) is responsible for conducting climate impact assessments. The World Meterological Organization (WMO) is supporting research and monitoring of atmospheric and physical sciences. The International Council of Scientific Unions (ICSU) is developing an international geosphere biosphere program that is focusing on the biological sciences.

EPA is also participating in the international arena in both multilateral and bilateral initiatives on climate change. On the multilateral level, we are working with the Department of State and other agencies to support UNEP and WMO. In particular, the U.S. Government endorsed the establishment of an Intergovernmental Panel on Climate Change by UNEP and WMO. We have nominated Dr. Frederick Bernthal, Assistant Secretary in the State Department (Bureau of Oceans and International, Environmental, and Scientific Affairs) to be the U.S. Representative. The panel, which we anticipate will begin to function later this year, will help ensure an orderly international process of activities on global climate change. Specifically, it will channel efforts into two tracks: the first to assess the state of scientific knowledge on the issue; the second to assess social and economic effects from a warming and potential responses.

EPA has a protocol in environmental protection with several nations, including the Soviet Union and the Peoples' Republic of

China. We have a strong bilateral relationship with the Soviets through the 1972 US-USSR Agreement on Cooperation in the Field of Environmental Protection, under which agreement we have conducted joint research on a wide variety of environmental issues.

EPA has had discussions with the U.S.S.R. on the following topics relating to global climate change: 1) future climates; 2) climate and paleoclimate studies in the Arctic; 3) measuring methane and ozone changes in Arctic and Antarctic regions; and 4) possible response strategies to climate change. This effort should make an important contribution to the proposed international assessment, led by UNEP and WMO, on global climate change.

Last year, EPA also signed a bilateral agreement with the Peoples' Republic of China, which included specific provisions on climate change. Potential areas for cooperative research include exchange of information and development of data on future energy development paths, emissions from rice fields and other sources, and concentrations of trace gases in remote regions. In general, these bilateral agreements provide an excellent opportunity to facilitate international cooperation and mutual understanding of this issue.

Technological and Policy Options

We are preparing our report to Congress that is to address options for stabilizing greenhouse gases, and on technological options that are available for reducing the rate of growth of CO_2

emissions in the United States and other countries, and in many different sectors. It is important to recognize that significant CO_2 emissions come from several different sectors. In the United States alone, most CO2 emissions are derived from fossil fuels which are distributed among various sectors as follows: approximately .48 gigatons of CO_2 per year are emitted from electric utilities; .34 gigatons from transportation; .23 gigatons from residential/commercial uses; and .21 gigatons from industrial processes. The United States is responsible for approximately 23% of world-wide emissions of CO2.

A number of supply-side and demand-side options exist for reducing the rate of growth of CO_2 emissions. On the demand side, significant improvements in end-use energy efficiency can be made, with the appropriate amount of lead time and public commitment. These improvements could occur in several sectors. The understanding that the ratio of energy consumption to GNP growth is not fixed and can, in fact, be sharply reduced through increasing end-use efficiency is becoming accepted in industrialized countries. Efficiency improvements have already enabled the United States to hold energy use to 1973 levels while expanding the economy by 40 percent. But efficiency improvements in the United States in such sectors as transportation and industry have leveled off in recent years. Continued energy improvements which will result from the normal turnover of the capital stock (e.g., automobiles, residential heating improvements, industrial processes) could reduce the growth in future energy demand by as much as 10-25 quads (8-20 percent) annually by 2010.

Improvements in end-use efficiency will help to mitigate critical problems that energy use causes for the global environment, the economy, and national security. Many end-use efficiency options exist, including making appliances, buildings and transportation more energy efficient, enhancing industrial competitiveness with energy-efficiency research, promoting least-cost utility services, and promoting international cooperation to encourage energy efficiency on a global basis. Each of these goals will make sense if saving energy costs less than providing energy when you include environmental costs in the comparison. Our intent is that these reports will assess the effectiveness and attractiveness of these options for controlling greenhouse gas emissions.

On the supply side, electric utilities are of particular interest. An increasing proportion of energy is being consumed as electricity. As the global demand for electricity continues to grow -- especially in the less developed countries-- electricity production will consume an increased proportion of primary energy. Fossil fuels are currently relied on for about two-thirds of global electricity production. Increased production of electricity from fossil-fuel power plants will lead to increases in emissions of CO_2 and other trace gases.

Less use could be made of fossil fuel technologies, and more use could be made of alternative energy sources such as solar, nuclear, and hydroelectric, to the extent that they are technologically and economically competitive in any given application, and can gain public acceptance. Fossil fuel use could also be shifted to natural gas, which emits much less carbon than does coal and oil for the same heating value. Such shifts, however, must be balanced against (1) the considerable investment already made in existing power generation and transportation systems, and (2) the potential, on a global scale, to increase reliance on strategically insecure natural gas supplies. (The U.S.S.R. accounts for 43% of world gas reserves, and the Middle East for 26% of the world's total.)

Advanced technologies that may significantly boost the efficiency of coal and other fossil fuel fired power plants are already under development in the U.S. and elsewhere. These new technologies will reduce the amount of fossil fuel that is needed to generate a kilowatt-hour of electricity. Consider, for example, the more efficient gas-fired combined cycle and cogeneration technologies that are available today. Combined cycle technology produces electricity with 45 percent efficiency -- as compared to a 30 to 34 percent efficiency for conventional fossil fuel boiler systems. The environmental benefits of this technology are also significant. CO_2 emissions can be reduced by as much as 65 percent for the combined cycle over conventional boiler systems. SO_2 and particulate emissions are less than one percent of equivalent coal-fired units. Emissions of NO_2 from a combined cycle plant are 57 percent of coal unit emissions. Gas-fired cogeneration systems have similar efficiency and environmental benefits.

The existing capital stock within the electric utility sector is aging. Electric utilities in this country will therefore soon be forced to make choices between alternative paths of development -- such as between extending the life of the existing capital stock or replacing or repowering it with new technologies. Trends in new orders indicate that utilities are becoming less interested in building new capacity in the form of conventional, large-scale central plants. Many utilities are attempting to extend the life of their existing conventional capacity. Some are investigating the benefits of refurbishing older coal-fired power stations with new, more efficient, cleaner technology, such as fluidized bed combustion and combined cycle coal gasification. There is, however, increasing interest in flexible projects such as efficiency programs, load management, cogeneration and combustion turbines. These latter options can have many environmental benefits, including lower CO_2 emissions. Several state governments have actively encouraged the introduction of efficiency programs and technologies that are more environmentally benign.

EPA's reports are also evaluating long-term strategies to limit climate change that might include technologies which produce no CO_2, as well as more efficient carrier/conversion technologies. Potentially attractive emerging technologies include photovoltaics, nuclear fusion, wind power, biomass, hydrogen, fuel cells, and advanced gas turbines. Renewables are especially appealing because they produce no CO_2. However, cost and performance levels to date have not made these technologies economically attractive. EPA will report to Congress on the many technological options that are more energy efficient and environmentally attractive. Both domestic and international implications are being considered.

In addition to these areas, the Administration is encouraging rapid ratification of the Montreal Protocol and will examine the need for further CFC reductions. (Six countries have already ratified the Montreal Protocol: the United States, Mexico, Canada, New Zealand, Norway, and Sweden.)

A careful assessment, however, must be made of any technological alternatives. First, the global warming issue is an international concern. In order to develop a responsible program, the U.S. government must consider the feasibility of achieving both domestic and international acceptance and implementation of policy initiatives. As we move to resolve the greenhouse issue, international collaboration must be pursued. The effectiveness of programs instituted by any one country could be overwhelmed by the lack of participation by other countries. Second, within any one country, no single sector is entirely responsible for the problem. The transportation, industrial, commercial, residential, and electricity sectors all contribute to CO_2 emissions. This suggests that no single policy initiative will completely mitigate man-made climate change. Third, any particular technological option must be analyzed for its effectiveness in reducing global CO_2 levels, the speed with which it can be implemented, and the costs which its implementation will impose on society.

Long Term Activities

In summary, Mr. Chairman, we are only beginning to understand the problem of climate change. It is therefore important to develop a strategy which is malleable and can accommodate new information.

EPA, along with other Federal agencies, intends to continue to be an active participant in the formulation of a policy-oriented Federal research agenda and in future debates over strategies to adapt to climate change or to limit emissions. The evolution of national policy in this area will be complex and the formulation of a coordinated international response may take many years. Much work remains to be done by the research community to understand emissions, the interactions of emissions with the biosphere, and the ultimate effect on man and the environment of increasing greenhouse gas emission levels in the atmosphere. EPA looks forward to working with interested federal agencies to exchange research and policy findings with other countries.

Mr. Chairman, thank you for your invitation to present testimony before the Committee. This has been a welcome opportunity to discuss EPA's efforts on this important and complex issue. I would be pleased to answer any questions you may have.

Senator WIRTH. Mr. Wayland, thank you very much. That was a superb piece of testimony, and we appreciate it.

We have been joined this afternoon by Senator Bumpers from the great State of Arkansas. Dale Bumpers was one of the first people, as many of us know, in the Congress and one of the first in the country to recognize the potential of atmospheric changes and what impact that might have on the country. He was involved early on in the CFC issue and has been a champion of the attempts to move the government and the country. Dale, thank you very much for joining us. Do you have a statement you would like to make?

Senator BUMPERS. Mr. Wayland, if you could magically cut off all of the trace gases right now that contribute to the greenhouse effect—and you stated in the first page of your testimony that the concentration CO_2, for example, has increased 25 percent in the last 128 years. I assume that CO_2 is like a lot others: it is an inert gas, is it not? It moves very slowly into the stratosphere.

Mr. WAYLAND. Well, it stays up there for a very long time.

Senator BUMPERS. How long does it take it, from the time it comes out the exhaust of my automobile, to get to where it is going?

Mr. WAYLAND. Well, there are some very sophisticated interactive processes between the upper atmosphere and the oceans as a sink for CO_2, and I can't give you an estimate of what that transport time is. Perhaps one of the other members of the panel is able to do that.

Senator BUMPERS. Dr. Albritton, do you know, or Dr. Watson?

Dr. SCHNEIDER. The kind of answers that people get to that question is at least many decades and possibly many centuries to completely get rid of it. But you could get rid of a substantial fraction——

Senator BUMPERS. No. I'm not talking about getting rid of it.

Dr. SCHNEIDER. Of the increment that we have injected is what I am talking about only.

Senator BUMPERS. Yes. I have heard that if we did nothing, it would be at least 100 years before we would be back to square one. But I am just talking about—for example, CFCs waft their way slowly into the stratosphere and destroy the ozone. And my question is on CO_2 does the same thing happen?

I know in 1975 when I was holding hearings on the ozone depletion theory, we were told that CFCs were inert gases. It takes 12 to 15 years for them to reach the 35,000–40,000 foot altitude. Now, my question is are CO_2s in the same category?

Dr. SCHNEIDER. In a crude sense, yes. It's different processes that are responsible.

Senator BUMPERS. It is different?

Dr. SCHNEIDER. Different processes are responsible for moving in the oceans and uptake by the trees, but your conclusion that it is 100 years as a ball park figure for how long it would take to get rid of the excess injected carbon dioxide is not a bad number.

Senator BUMPERS. Well, really I think the point I am trying to get to—and I'll just ask you the question. If we could magically cut off all of the contributing gases right now, we would still have considerable additional warming as a result of what damage it has already done, but we have not yet felt the full effect of. Is that correct?

Dr. SCHNEIDER. If you cut off the continued emissions, but left it at the present level, which is above that that nature would appear to want by itself, then we still probably have maybe gone only halfway, and we would still have another at least several decades of additional warming to take. That is what most present modeling would suggest.

Senator BUMPERS. Is the biggest contributor to the ozone depletion—of course, CFCs also contribute to the greenhouse effect I understand too, but is freon the biggest contributor of CFCs on our planet right now, Dr. Watson?

Dr. WATSON. Freon is a trade name for Du Pont's products. Fluorocarbons 11 and 12 and 113 are the three largest produced CFCs, and they are produced not only by Du Pont, but by Allied and several companies internationally. So, freon is a trade name. It is not generic for a specific molecule.

Senator BUMPERS. Well, I understand that. But is it a contributor to both CFC 11 and 12?

Dr. WATSON. Yes, and they are both greenhouse gases, such as 113. That is why the Montreal Protocol was so important. It helped to mitigate greenhouse warming and to partially safeguard the ozone layer.

Senator BUMPERS. But according to your map here, Mr. Wayland, CO_2s contribute about 50 percent of the problem. Is that correct?

Mr. WAYLAND. That's correct. And as you think about how you might respond to the problem, your point about transport times and conversion times and so forth I think is an important one because the CO_2 is probably going to be there for thousands of years, whereas methane has a much shorter atmospheric lifetime of 6 to 8 years, so that if you begin to realize some improvements there, you may be able to see some improvements in the environment in the short run, although it represents a smaller overall contribution on the order of 18 percent as shown in that chart.

Senator BUMPERS. If there had been none of these trace gases released in the last 100 years, what would the temperature of the earth be right now?

Dr. SCHNEIDER. That is a difficult question, but current sum of thermometers around the world suggests that something on the order of 1 degree Fahrenheit cooler, but there is a degree of uncertainty of perhaps a half a degree Fahrenheit associated with that in either direction.

Senator BUMPERS. Do you agree with that, Dr. Albritton?

Dr. ALBRITTON. Yes.

Senator BUMPERS. Now, you list rice production, in which I have a small parochial interest, as one of the biggest contributors of methane. What is the chemical reaction of rice production that produces methane.

Mr. WAYLAND. Well, it is wetland rice production where there is a decomposition of organics in the wet layer, and actually the rice plant acts essentially as a wick to take that methane into the atmosphere. It is just a typical decomposition process. Not all rice production is equally guilty in this respect. High yield rice production, for example, gives you a relatively less significant methane problem than low yield rice production. Dry land rice production is not particularly a problem at all.

Senator **Bumpers**. Now, if we could elect you king for 10 years, and you could deal with this problem in a very autocratic way, what would be the first thing you would do?

Mr. **Wayland**. I'm not sure who is going to get coronated here first.

Senator **Bumpers**. We will make it God, if you want to. [Laughter.]

Do you read Far Side? [Laughter.]

Do you remember the cartoon of the dinosaurs' convention?

Dr. **Schneider**. Yes.

Senator **Bumpers**. The ice age is coming. We are surrounded by predators and we have a brain the size of a pea. [Laughter.]

See, we have a brain the size of a cantaloupe and the political will the size of a pea. [Laughter.]

So, I am going to put them on all fours with you and you just tell us how you would deal with it.

Dr. **Schneider**. Since I am not a Federal employee and not subject to the Hatch Act, I don't mind playing king first. [Laughter.]

A lot of the things that I would do are exactly what is in the 1988 Energy Policy Act. The first thing I would do is I would look very, very hard at how we can improve the energy efficiency of both this country and the rest of the world, the single most important item.

Senator **Bumpers**. Well, you certainly wouldn't favor reducing the CAFE standards then, would you?

Dr. **Schneider**. No, I would not.

Senator **Bumpers**. And you wouldn't either, would you, Mr. Wayland?

Mr. **Wayland**. Senator, I have to say that that is not an area of EPA's responsibility. [Laughter.]

Senator **Bumpers**. Go ahead, Dr. Schneider. I want you to continue with this. I want you to talk about reforestation, energy conservation, energy efficiency. I want you to sort of go through those on a priority basis for me.

Dr. **Schneider**. Well, as I said, I would think that energy efficiency is probably the number one way, and the reasons were partly given in my testimony. In brief, simply that the biggest gains to be made in terms of reducing the emissions of greenhouse gases can be made through energy efficiency while at the same time providing other benefits to the society. Therefore, you get the highest leverage from your investments, other benefits such as reducing acid rain, reducing health effects of air pollution in cities, decoupling dependence on foreign supplies, and as many, many studies have shown, getting energy services at least cost. The issue is not simply providing more energy to deal with the growing economy, but providing energy service to fuel a growing economy, and those energy services, if they can be done at least cost through efficiency, that certainly makes sense. So, when you have high leverage, that to me is a sensible kind of a policy for us to take at a collective level such as in the Federal Government.

The second one you mentioned also. Deforestation is a very good one. Before one afforests, one also has to halt deforestation. And that will involve cooperative efforts in particular with developing countries for whom deforestation is often not a choice but a stop gap measure from a combination of economic deprivation and population pressure. And we have to help, as Senator Wirth said, provide alternatives to the pressures that are creating that deforestation.

It isn't just simply again a question of greenhouse gases with deforestation, but ecologists will tell you that the problem that they are most concerned with, at least most I've spoken to, is the preservation of the diverse species on the planet and a large fraction of them live in tropical forests which are under assault for reasons I had mentioned. And you again get high leverage if you can halt deforestation to a large degree because you both reduce the injection of greenhouse gases and you help to preserve species. But we will not be able to do that one alone.

Other measures you can take——

Senator **Wirth**. Is deforestation something we can do domestically as well?

Dr. **Schneider**. Reforestation, yes.

Senator **Wirth**. You now, deforestation/reforestation, other than an international component, does it have a domestic component as well?

Dr. **Schneider**. Yes. There is a domestic component about that too. And, indeed, the U.S. Forest Service, for example, is also seriously concerned with the issue. I know personally. I helped sponsor a meeting for them at my institution last year, and we are having another one on forest fires. They are very concerned about what the forest fire potential will be from increased warmth and perhaps dryness particularly in the U.S. West. And this is an issue of considerable concern to them of which they are now sponsoring studies.

Senator **Wirth**. They have talked about exploding forests. What does that mean?

Dr. **Schneider**. That I don't know.

Senator **Bumpers**. I heard a rule of thumb that one square mile of forest normally is sufficient to absorb CO_2 of one megawatt of power generated by coal. Have you ever heard such a thing?

Dr. **Schneider**. I have heard such things. I can't remember if those are the numbers. But I have seen calculations of exactly how much forest would have to be grown in the world to hold the greenhouse emissions—I'm sorry—hold the buildup of CO_2 to half of its present amount over the next 50 years. And while it is feasible, it is a very big number. I think you would have to grow forests something on the order of the size of the State of Alaska.

So, while it is economically and physically possible, I don't think that we can consider that as a sole strategy. I think that we have to try to slow this problem by a lot of things, some of them little things. When you add a lot of little things up, if you can cut the problem in half, you have been effective. And again, that is what I appreciate in the act is that it operates on many fronts.

A third category of——

Senator **Wirth**. Why don't we just stick with forests with a parochial interest for a minute. There are a lot of concerns that with a much warmer atmosphere, the forests are drying out. When they say exploding forests or whatever, the fires hit very, very rapidly. This year, for example, we have had much, much hotter, faster forest fires and much earlier than we normally do. The kind of forest fires that we have had in Montana, Wyoming, Utah and a little bit of Colorado have been much earlier than normal too.

Dr. **Schneider**. Yes, that is my impression. One or two of my colleagues in the Forest Service have confirmed that impression. And they are still worried for the major season yet to come in California.

Senator **Wirth**. Finally, what does a reforestation or deforestation strategy say to us about another topic of concern on this committee, and that is the destruction of the Tongass National Forest in southern Alaska?

Dr. **Schneider**. Well, without getting into the specific question of that one, anytime one destroys forests, if the trees decompose or are burned and then not replaced by trees of comparable size, you do add some greenhouse gases, in this case mostly CO_2, to the atmosphere.

We shouldn't be putting down steps which only seem to make a few percent difference in the problem. I think that one of the ways that we deal with this problem is to do a lot of little things. And to me slowing it down is very critical for the reasons I had said earlier, namely, the rate at which we are increasing the greenhouse gases is what I most fear because that rate suggests climate change potential 10 or more times faster than natural rates. So, slowing that down both buys us time to adapt and perhaps even take advantage of some circumstances, and at the same time allows natural ecosystems more time to adapt. The faster we change things, the less likely it is that they will be beneficial, and the faster we change things, the less likely nature can keep up. So, we shouldn't overlook any way that we can slow the problem down.

Senator **Bumpers**. Dr. Watson, let me ask you this question. Is there any point at which the stratosphere is saturated with CO_2s and methanes and so on so that it doesn't really make any difference whether you go beyond that or not? Do you understand my question?

Dr. **Watson**. Yes. I think any normally predicted rates of increase will always have an impact. I don't believe that we could ever envisage in the near future, even in the next few centuries, adding so much CO_2 or methane or fluorocarbons it would not have a significant impact on the amount of ozone. It does not saturate.

Senator **Bumpers**. And finally, do any of you know of any, perhaps I should say, natural antidote that we might consider or any manmade antidote that we might consider that could reverse the problem or restore the CO_2s or something like that?

Dr. **Schneider**. Well, we have already mentioned that one could certainly slow it down by reforestation. But you also have to recognize that once those trees that we have grown are ready to die, when they die, if they decompose, they are going to give that CO_2 back. So, then we have to find something else to do with them. The idea of doing that would be to slow it down. But then we would have to store them somewhere. Whether you haul them to Antarctica, bury them in mines or cover them in plastic, you still will have the problem of getting that CO_2 out sometime. So, it can help.

It can slow it down. And if you can slow it down, then the oceans can help you along by taking it out.

There are other things that have been proposed. People are a bit fanciful in the line of what we call geoengineering. Spreading lots of phosphate or nitrogen fertilizers in the moderate productive zones, in the oceans, could make phytoplankton grow faster and that would suck CO_2 out of the air. What that would do to ocean biology is a great speculation.

Others have suggested, as I had mentioned earlier, that you use high-flying aircraft to spread dust up in the upper layers of the atmosphere, but then you run the risk of the intervention being a cure worse than the disease. And we have no legal instruments that deal with that. And I expect that we will hear more and more along these lines.

And then finally, there is some discussion about actually freezing the CO_2 out at the power plant stage or where the industrial fires take place, and then pumping it into the oceans directly thereby short-circuiting the time, the few hundred years, that it might be in the atmosphere before it is eventually removed in the oceans. And there has been some engineering study on it. Most of it is considered unfeasible simply because of the cost. It doubles the price of the energy, and you still would get the CO_2 back, some of it back, again maybe hundreds of years down the line, but that clearly would reduce the big pulse.

So, there may be some geoengineering that can be done, but when you geoengineer, if nature throws you a few bad years, you then may have to take the blame for those years. And again, we haven't looked at our legal and international relations institutions that decide whether this world is able to cooperate to the extent that it will be modifying the planet when there is still large uncertainty.

Senator BUMPERS. How about substitutes for CFC 11 and 12? Do we have suitable substitutes coming?

Dr. WATSON. Most of the large producers of CFC, such as Du Pont and Allied, are working closely to try and find what they would call safe substitutes for CFCs. They have identified probably half a dozen such molecules, but they have to go through toxicological testing. The one thing that is good at least about fluorocarbons 11 and 12 is they are totally nontoxic. Obviously, if you replace those gases in our refrigerators in our homes, you would like the substitute to be equally nontoxic. That process of study on the toxicological properties of a gas tends to take 2 to 4 years. So, I hear only optimistic comments that within a period of 4 to 6 years one may well have safe substitutes.

However, I think we are going to have to look quite carefully what an acceptable level of chlorine is. It is quite clear to me the Antarctic ozone hole is here to stay for a considerable period of time, and the question is do we want to cut chlorine levels back 50 percent, 80 percent, 90 percent or 95 percent. And if we get into the levels of the 90 to 95 percent region, we are going to have to look quite carefully at exactly what are the lifetimes of these substitutes that are acceptable.

I think industry is going to need a clear signal from governments around the world where they should invest large amounts of money into substitutes if after they find substitutes for 11 and 12, we then say, ah, but the lifetime of the substitute you have is still 5 or 10 years. It is still putting a few percent of chlorine into the atmosphere. That is not acceptable.

So, I think we are going to have to look quite carefully at what level of cutback of fluorocarbons will eventually be needed.

Senator **Bumpers**. Thank you and thank you, Mr. Chairman.

Senator **Wirth**. More on policy options as well. Let me ask you. You were mentioning Dr. Schneider focusing on the energy side of the strategy, the predominant responsibility that we have here. You touched briefly on solar. What are the other energy production alternatives that we ought to be examining?

Dr. **Schneider**. Well, again, the bill has a good list of them. First we have coal which is primary and which is a large energy source which will last for a long time. And many people like it because it is considered to be a least cost energy option. As you know, the trouble though is that that cost is often defined in terms of simply the economic costs without counting the environmental damage at the stack, and that is why, obviously, we are having a hearing because we recognize those issues.

One can clean the coal to some degree. For example, you can scrub out some of the sulphur which is responsible for acid rain which is creating friction between us and Canada. And while certainly that is laudable from that point of view in helping to correct the problem of acid rain, you do pay a slight energy penalty. Therefore, you would be actually having even more CO_2 generated in that process.

Other fuels involve oil and gas, fossil fuels.

Senator **Wirth**. Is there a clean coal technology that can focus on the CO_2 problem?

Dr. **Schneider**. Well, my understanding, although I am not an expert in energy technology, is that there are a number of processes that can be done, different kinds of turbine designs and cogeneration and so forth, that can produce considerably more efficient power at power plants or in steel mills. But there is a fact of chemistry which is that the energy content per kilogram, if you will, or per pound of coal, is simply less than that of oil and less than that of natural gas.

So, whatever the improved technology that we develop—and we should develop them—you will probably always find that ratio being held. So, while we have the coal, we need even cleaner technologies, for example, than we have today to bring coal to the emission standards of what would happen if you fuel-switched to methane using the present technologies.

There are other energy alternatives that you mentioned.

Senator **Wirth**. So, we should maintain an aggressive clean coal research program. That is a prudent thing to do.

Dr. **Schneider**. Well, you want to maintain a clean fossil fuel program for which coal is one of the fuel options. But whether you——

Senator **Wirth**. Coal tends to have a special constituency in the United States Senate. [Laughter.]

Dr. SCHNEIDER. Despite my non-evasion on the Hatch Act, I will evade this one because that is an issue I don't spend enough time on.

Senator WIRTH. Is there any way of burning coal that captures the carbon? Is that theoretically possible?

Dr. SCHNEIDER. Yes. I had mentioned in response to Senator Bumpers that people have made calculations about taking the CO_2 out, and you would have to use a substantial fraction of the energy generated to, as I understand it—and there are people who know more about this whose names I could give you later on for the record. You have to essentially freeze it out, turn it to I guess a liquid and then pump it into the oceans with a very high energy penalty, but it might be possible.

I have also heard of people arguing that one could use that CO_2 for tertiary oil recovery, and there might be other applications where it would stay buried. But what the economics of that kind of technology is I can't comment. I certainly think it is appropriate to investigate it, however.

Senator WIRTH. In terms of other sources of energy, we have another vote. Let me just ask you this. One constituency group in the United States that has been very concerned about the piece of legislation is the coal constituency. Another is the constituency looking at nuclear energy, very concerned that in the legislation we have clearly said we have to start all over again in nuclear and see if we can find a safe and cost-effective nuclear energy source. And we have a responsibility to do that as well. And just as many of the coal people say don't talk about coal because that is a good thing, there are other people who say don't talk about nuclear because that is a bad thing. What is your comment on nuclear?

Dr. SCHNEIDER. Well, I was afraid you would ask that. I have to tell the truth.

Senator WIRTH. The Hatch Act doesn't apply.

Dr. SCHNEIDER. I have never been personally a fan of nuclear power plants as they have been largely developed and deployed in the United States. In particular, I haven't liked siting them in high population centers, for example. Risk is classically defined as probability of the accident times the consequences. And it is hard to control the probability, although there are things you can do. But you can control the consequences with containment vessels as the Soviets learned, and you can also control the consequences by siting to some degree by having fewer people exposed.

But my understanding of nuclear power research is that there are a number of cycles that are inherently "safe," unlikely or impossible to melt down and other issues where you might be able to minimize the proliferation problems associated with nuclear power although we still have waste disposal questions. And I certainly would not personally say that one should foreclose any option with regard to research.

I would hope that you would not embrace an immediate replacement of fossil plants with nuclear plants since I think at least cost, you would probably be better off in the near term by replacing fossil plants with efficiency and perhaps some mix of fuel switching, but I would not leave nuclear out of the equation in the long run, although it may not be the nuclear that is now practiced.

The same can be said also for solar, in particular photovoltaics, which again I am not an expert in, but I have seen and heard from various people that the costs of producing electricity from photovoltaics are coming down. And I think if that technology had the kind of subsidy that nuclear and coal did, both in terms of Federal research and in demonstration projects, it might very well be another one of those components of our future energy system that we would want to turn to in 20 or some odd years down the line.

Also, biomass. Biogas, in particular, may be something very valuable in those countries with substantial agricultural wastes or forests that could be grown in plantation style.

So, again, a lot of little steps. If you can get 5 or 10 percent of the CO_2 problem solved with each of these, and you add them all up, if you cut the problem in half, that is close to what the bill is hoping to accomplish in the long run. So, I think again we shouldn't foreclose any option, but we need to recognize that each of them have their own separate set of both constituents and difficulties.

Senator WIRTH. The bill requires the Department of Energy to come back to us with a least cost strategy for reaching the CO_2 reduction goals that are in the legislation which is one way of saying immediately, obviously, we are not suggesting—and nobody would believe this was possible—to replace current fossil fuel plants with a lot of nuclear plants, although there are a lot of shrill voices out there that suggest that may be that is what we are doing. That is hardly the case.

What we do is have a least cost strategy and at the same time saying we really have to do this research not only in the nuclear area to see if it is possible. The bill also calls for a lot of cooperation internationally with other countries who have had other experiences with nuclear. We ought to pool our resources, pool our expertise. This is a logical thing to do. And let's see if down the line, in fact, we can find and develop a safe and cost effective nuclear program.

It seems to me that if we are again dealing with what do you say to the Chinese program—here is a country of a billion people embarked upon a very aggressive industrialization program—what do you say to them? Don't burn coal? Of course, not. That is preposterous for us to assume that we could say that sort of thing, but rather it seems to me we have an obligation to see if in fact working with other countries we can develop a central source of power. And maybe the one that works is nuclear. Maybe we are going to find some kind of a solution to the coal problem.

But we have to pursue all of these areas just as in more rural decentralized areas we have to aggressively pursue the solar option. That would appear to be something that might be a likely replacement in rain forest areas for the energy and for the power sources that come out of burning the rain forests. Those are very decentralized economies in one in which it might be that a cost effective solar program could be substituted for the people there. We have to give them some sort of an answer to slash and burn as well.

Mr. WAYLAND. Just the availability of small cooking stoves, which are very much more efficient than the open cooking fires with cow chips that you see all over the third world, would make a substantial difference.

Senator **Bumpers**. Say that again. I didn't understand you.

Mr. **Wayland**. I suggested that simply substituting small, economical cooking stoves for open burning cooking fires that are prevalent in much of the less developed world would make a not so insignificant contribution.

Senator **Wirth**. We have another vote, a 15 minute vote. And we will have to break for a few minutes. And then if we might come back, we will do that, Dr. Albritton, Dr. Watson. We will come back to the two of you, if we might do that. We will be back in about 15 minutes.

[Recess.]

Senator **Wirth**. If the committee would come back to order. The remaining two further witnesses have been part of the discussion, but have not had a chance to testify yet. Dr. Watson, why don't you go ahead. And we will include your statements in full in the record. Please proceed. Thank you very much.

STATEMENT OF DR. ROBERT T. WATSON, DIRECTOR, GODDARD INSTITUTE FOR SPACE STUDIES, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. **Watson**. Thank you, Mr. Chairman, for the opportunity to talk today. I would like to note, however, unlike EPA and DOE, NASA is not a policy agency. It is strictly a scientific agency, and so during my discussion I will primarily talk about science, scientific uncertainties and scientific programs. That is not to say, of course, that policies cannot be enacted today that deal with, obviously, controls on CFCs, energy conservation, energy efficiency, et cetera.

It is quite clear that the ozone issue and the global warming issue are just two of the clean environmental issues that we must attack aggressively both scientifically and politically. It is clear, however, there are significant scientific uncertainties, and we believe at NASA that a whole new approach to science is required if we are to reduce these scientific uncertainties.

The earth, as we all know, is a dynamic system. It changes on all time scales. It is affected by both natural phenomena and by human activities. Consequently, we have got to stop looking at the earth as a separated system of the oceans, the land and the atmosphere. We have to understand the interactions between these components of our atmosphere.

We have also got to recognize that global climate change is not the only key issue that we should be dealing with. We have to look effectively how will changes in land use affect—and soil erosion, ultraviolet radiation, changes in the abundance of trace gases which will give us more acid precipitation—how will they change the productivity of both managed and unmanaged ecosystems and the biogeochemical cycling within these ecosystems. So, we have to look at a global change program that goes well beyond just simply global climate change.

One of NASA's main goals and objectives is to conduct an effective and productive space and earth sciences program which clearly expands the human knowledge of the earth, both how it varies naturally and how it varies in response to human activities. We believe this will require a comprehensive earth science research program utilizing space-based suborbital data. It requires observations on the land and in the sea, a major component of laboratory work and clearly major theoretical and model development studies. It clearly also has to have both international as well as national participation.

NASA is working very closely with all the other science and policy agencies in Washington through the Committee on Earth Sciences and with the National Academy of Sciences to develop a global change program that will clearly be international in scope. I believe that it will be essential that we can put together a global change program that is coordinated internationally if we are to have any success of significantly reducing some of the key scientific uncertainties we have today.

A key element in the NASA plan will obviously be to continue a very vigorous program of research and analysis, process oriented studies. In addition, we believe it is important to fly satellites such as UARs, the upper atmosphere research satellite; TOPEX, the ocean topography experiment; the NASA Scatterometer that will look at wind stress at the ocean's surface. And a major plan of NASA is to implement the EOS, the Earth Observing System which are the polar platforms component of space station. While very expensive, we believe EOS will be a major component of our plans in the future.

Senator WIRTH. Is that a would be or is?

Dr. WATSON. It is clearly not approved at this moment. It is something that we would clearly like to have approved by the administration and, obviously, to be an accepted program within the next few years. We are doing studies on EOS at the moment. Feasibility studies, instrument development studies add up to on the order of a few million dollars a year. Obviously, when EOS is fully proposed to the administration and to the Hill, it will be a program that is of many hundreds of millions of dollars. And so, it is not an approved program yet, but it is clearly in our plans for the future.

Senator WIRTH. We were looking for it in the budget and couldn't find it.

Dr. WATSON. All we have at the moment is what we call an ATD line, a fairly small line. It is $15 million in 1989 to do more studies of instrument concepts and platform concepts. We would hope to present it to the administration in 1991 as a new start which would then have a fairly significant bill attached to it.

There are some things we learned, though, in the ozone-CFC issue that I think we must remember. I think there must be a clear separation between scientific assessments and policy assessments. This was not done in acid precipitation and caused a mess. There must be a continuous dialog, however, between the science agencies and the policy agencies. We need to understand what policymakers and regulators need in the way of scientific information, and we need to be able to present it in a digestible form.

It is crucial I believe that when we do scientific assessments they are international in scope not national. I think if we look at the ozone issue, one of the most important steps we took was to make the scientific assessments international rather than being parochial and national. And it was really the foundation of the Vienna Convention and the Montreal Protocol that we had the scientists of the world talking with one voice. So, when there were debates between nations as to what the policies should be, they were not debating the science; they were debating economics and political considerations.

We also believe, as I said earlier, there must be very close cooperation between the science agencies. For once I believe the science agencies such as NASA, NOAA, NSF, EPA, DOE, USGS are working together. We are trying to put together a global change program recognizing how our programs can best compliment each other. I think this is very, very important for the future.

We do have to recognize, however, that we don't fully understand the climate system. We don't understand the forcing. Now, of course, there are natural forcings, changes in solar output, changes in volcanic output. There are also human-induced changes in the climate system such as changes in the atmospheric abundance of trace gases, also changes in land use and land cover.

Now, unfortunately, I would have to disagree with my colleague from EPA. I do not believe we understand why methane is changing. He had a very nice pie chart showing 24 percent for rice. I would have to say that is uncertain by a factor of two or three, as each of the other elements.

While we might be able to enact policies to control CFCs and we might be able to enact policies to limit or control CO_2 emissions through energy conservation, energy efficiency, I believe it is grossly premature to consider trying to enact regulations to control nitrous oxide and methane, both gases that are increasing in the earth's atmosphere. Both gases affect ozone and affect global warming.

I really do believe there is a significant uncertainty as to why methane is changing. We don't really know which of the sources is changing or whether it is even the sinks of methane in the atmosphere. The whole of tropospheric composition is changing. That in itself changes the atmospheric lifetime of methane.

So, I believe we need a very active research program to look at the biological and geological processes that control gases such as methane and nitrous oxide to look at the fluxes in and out of the atmosphere. Now, the problem is we don't fully understand those fluxes today, and with a changing climate, we may well expect changes in those fluxes.

One thing that we know is that there is a large amount of methane tied up in the clathrates at high polar latitudes. If there were to be a global warming, it is not inconceivable that could enhance the rate of methane release in a very positive feedback on the global warming situation. But that is speculation. We just don't know.

Clearly, we need a strong research program to understand each of these trace gases so that we can have a sensible policy to control gases such as methane and nitrous oxide.

Senator **Wirth**. How long has NASA known that it wanted to undertake this kind of a research program?

Dr. **Watson**. We have had an evolutionary program, always through the ozone situation. We have both a climate program and an ozone program. And we have recognized since about the last four or five years that methane has been changing. We put forward to the administration a small program called interdisciplinary research, only about $1 million per year. And we used some of that money, a large part of it, plus a significant——

Senator **Wirth**. So, that is what you asked for was $1 million?

Dr. **Watson**. Yes, and it has never been augmented since.

Senator **Wirth**. Is that all that NASA has asked for?

Dr. **Watson**. On that particular program the answer is yes. Most of NASA's requests——

Senator **Wirth**. But generally on the research that you think ought to be done on global change and atmospheric research and so forth is $1 million?

Dr. **Watson**. That is effectively was what has come through from the administrator of NASA. Most of the big augmentations have been on space station and——

Senator **Wirth**. You know what I am driving at. We have one situation after another in which the administration has, since 1981, very systematically said no to looking at various research in the areas of climate change and global warming and adaptation and research that ought to be done and so on. I realize the Hatch Act status, to use Dr. Schneider's words, but I just wanted to say I understand that and that is the situation that has gone on for a long period of time. Many of us have been working on that, but to no avail.

Dr. **Watson**. I think it would be fair to say that NASA has pursued a strong earth sciences program where the budget has at least kept pace with inflation and in some cases larger than inflation. But clearly also it has put large initiatives forward, such as space station, getting the space shuttle back and operational, as a higher priority. But I do believe that NASA has gone at least aggressively to keep pace with inflation.

Whether or not one should have a larger program, I think one could quite clearly state that there are a significant number of scientific uncertainties and more money in earth sciences would not be misspent.

I think there is a whole series of uncertainties that we have to look at. And many of them are very, very complex feedbacks. If there were to be a change in climate, clearly the amount of water vapor in the earth's atmosphere would increase just through increased relative humidity. We have to understand that feedback between water vapor and the climate system. The amount of ice will change globally, especially sea ice. We have to understand how that affects albedo in the feedbacks.

A critical one is understanding clouds. It might be surprising, but even a small change in clouds or the altitude at which clouds appear could have a significant effect on the sign of the feedbacks between clouds and the atmosphere.

We need to understand basically the thermal response to the ocean. It isn't only the magnitude of climate change that is important, but it is the rate at which climate changes. Until we understand atmosphere-ocean interaction, we are clearly not going to be able to quantify as well as we should the rate of change of atmospheric temperatures.

We also have to be worried about could the climate have many metastable states. Could it flip from one state to another? I think there is a very important message in Antarctic ozone that we should not ignore. We had a very aggressive program, we being the U.S. Government, to try and understand atmospheric ozone for more than a decade now. We thought we understood to a fair approximation what controlled atmospheric ozone. Unfortunately we were caught by surprise. The Antarctic ozone phenomenon was completely unexpected and completely unpredicted. Antarctic ozone changed quickly and unexpectedly. I think we have to be concerned that the climate system may not change linearly, may not change slowly. It could jump from one metastable state to another. That is something that we have to bear in the back of our minds.

So, in summary, we know a lot about the climate system. There is major reason for concern. We are clearly loading the atmosphere with trace gases. These trace gases clearly will change the radiative budget of the atmosphere. There are some questions on the timing of the change. There are some questions on the magnitude of the change. But clearly the system is predicted to change.

The NASA program will be an aggressive program that utilizes both space and ground-based data. We will have a program that looks at both the atmosphere, the ocean, the land. We believe we need to pursue aggressively interdisciplinary and multidisciplinary science, and we believe that we need to do this coordinated both nationally and internationally.

Thank you.

[The prepared statement of Dr. Watson follows:]

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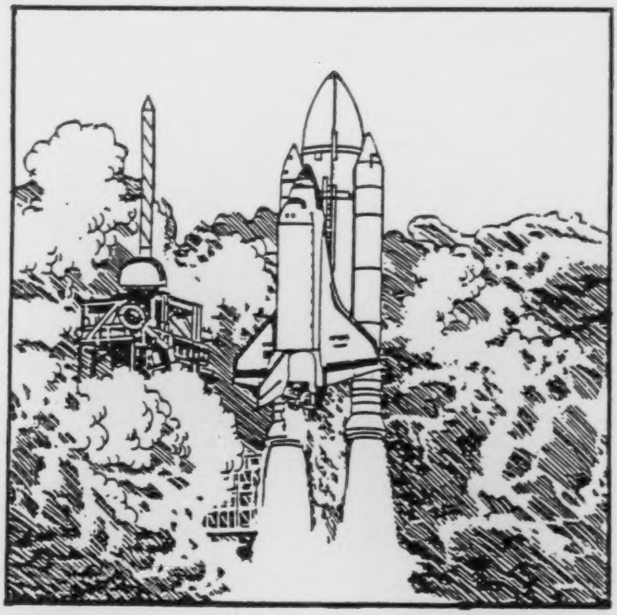
August 11, 1988

Committee on Energy and Natural Resources

United States Senate

Statement by:

Dr. Robert T. Watson
Earth Sciences and Applications Division
Office of Space Science and Applications



100th Congress

STATEMENT OF

DR. ROBERT T. WATSON

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES

UNITED STATES SENATE

Mr. Chairman and Members of the Committee:

I am pleased to be here today to discuss NASA's programs in global climate change research. In this testimony I would like to describe for you briefly the type of scientific information needed to predict future climate states, scope and content of NASA's Earth System Sciences program, and how it is coordinated with the scientific community and other federal and international agencies and programs.

NASA recognizes that scientists have recently presented important data which seem to indicate that: (i) present global temperatures are the highest in the period of instrumental records with the four warmest years in the past century all occurring in the 1980's; and (ii) the temperature record indicates that the temperature of the atmosphere has increased by between 0.5 and 1.0 degree Centigrade since the late 1800's, consistent with that predicted to have occurred over this period because of the greenhouse effect, primarily due to the increased atmospheric concentrations of carbon dioxide. It should also be recognized that model calculations indicate that the world's oceans can take a decade to as much as a century to equilibrate with the changes in radiative heating induced by trace gases, thus suggesting that we may have realized only half of the predicted equilibrium surface warming from the past emissions of trace gases.

However, our understanding of the climate system is far from complete. Therefore, NASA is committed to conducting a comprehensive Earth Sciences research program, in coordination with other federal agencies, in order to reduce some of the current uncertainty in scientific understanding.

Background:

It is evident that the Earth is a planet characterized by change. We have entered an era in which the human race has achieved the ability to alter its environment on a global scale. The ozone and global greenhouse warming issues which are presently at the center of attention of many scientists and policymakers are just two of the interrelated environmental issues we face today.

To gain a scientific understanding of how human activities will affect the Earth's environment requires a new approach to Earth sciences. The Earth's environment is a dynamic system that changes on all time and space scales. These changes are caused by both natural phenomena and human activities. It is vital that a scientific understanding of the Earth system be obtained on a global scale by describing how the environment's component parts and their interactions have evolved, how they function, and how they may be expected to evolve in the future on all time and space scales. Specifically, the immediate challenge is to develop the capability to predict the environmental changes that will occur in the next decade to century, by both natural and human influenced processes. This will require a nationally and internationally coordinated program of interdisciplinary research to investigate long-term, 10-100 years, coupled physical, chemical, and biological changes in the Earth's environment recognizing that land, atmospheric, oceanic, and biospheric processes are strongly coupled on a variety of temporal and spatial scales. Wise policymaking requires this improved scientific understanding of our planetary life support system.

While climate change (global and regional) induced by changes in greenhouse species, land use practices, global ecology, and atmospheric and oceanic circulation is one, and perhaps the major, area of interest in understanding Global Change, it must be remembered that there are additional global environmental issues that are important both scientifically and societally. Examples of Global Change issues which are of concern independent of the climate issue include understanding how changes in land use practises, soil erosion, ultraviolet radiation, and the atmospheric abundance of trace species (carbon, nitrogen, sulfur and halogens) can alter the productivity of managed and unmanaged ecosystems and the biogeochemical cycling of nutrients within such ecosystems.

Planning and Agency Roles for Global Change Research:

One of the eight NASA Agency "GOALS and OBJECTIVES" is to "Conduct an effective and productive Space and Earth Sciences Program which expands human knowledge of the Earth, its environment, the solar system, and the universe" with a goal to establish, in cooperation with the scientific community, other federal agencies, and international organizations, an active long-term Earth Sciences Program.

To accomplish this goal requires a comprehensive Earth Science Research Program involving space-based, suborbital, land-based, and sea-based measurements; laboratory, theoretical, and instrument and model development studies, with national and international cooperation and participation.

The Earth System Sciences Committee (ESSC), which was established in 1983 by the Advisory Council of NASA, has provided NASA , NOAA, and the NSF with a clear definition of their specific roles in Earth System Science. The goals and objectives of the research program formulated by the ESSC are totally consistent with the proposed National Academy of Sciences/National Research Council (NAS/NRC) and the International Council of Scientific Unions (ICSU) research programs known as the Global Change or the International Geosphere Biosphere Program (IGBP). These programs are still being formulated and will build upon the many excellent ongoing national and international research programs in Earth sciences and will not duplicate or replace them.

NASA is cooperating fully in the detailed scientific planning of such a program in conjunction with the scientific community through the NAS/NRC and ICSU, and implementing the U.S. component of this program with the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), the Department of Energy (DOE), and other government agencies.

NASA is an active participant in the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET) efforts to coordinate Federal global change research efforts through the Committee on Earth Sciences (CES) which was established by the Office of Science and Technology Policy (OSTP).

The NASA implementation plan is based on continued strong support for the Research and Analysis programs described below, expansion of the concept of the interdisciplinary research program, completion of approved satellite programs including the Upper Atmospheric Research Satellite (UARS), the Ocean Topography Experiment (TOPEX), the NASA Scatterometer (NSCAT), and implementation of the planned Earth Observing System (Eos) which will make use of the polar platforms being developed as part of the international Space Station effort.

Any future interdisciplinary, integrated Earth Science program, will require an interactive Global Resource Information System. NASA has initiated a number of pilot programs to establish the requirements for such a system. Specifically, the two critical issues being addressed are:
(1) how best to create a data management system capable of dealing with interdisciplinary and multidisciplinary questions of global scope, and
(2) how best to provide, in advance, for handling the unprecedented flow of digital information that will be generated by the polar orbiting space platforms planned for Eos.
Additionally, NASA and the United Nations Environment Program (UNEP), working with the Department of State, have established a Global Resource Information Database system (GRID).

Of course, NASA understands the fiscal realities that confront us, and will continue to evaluate our Earth System Science efforts, like the unapproved Eos, in the context of the rest of our space program.

Separation of Science and Policy:

In considering how best to coordinate global change research programs, there are several key lessons to be learned from the chlorofluorocarbon (CFC) - ozone issue. The key lesson is that it is vital for there to be a clear separation of responsibilities between the scientific agencies and the policy-makers. Therefore it is also essential that:

* there is a clear separation between scientific assessments and policy assessments;

* there is a continuous dialogue between the scientific agencies and the regulatory agencies and policy-makers to ensure that the scientific information that is required for decision making is obtained and presented in a digestable form;

* the participants of the scientific assessments are the the best scientists in the world and are also representative of the international scientific community;

* based on the scientific assessments the scientific research programs are developed and implemented by the scientific agencies in concert with the scientific community, including the National Academy of Sciences (NAS) and other advisory bodies;

* there is close coordination among the scientific agencies charged with conducting scientific research;

In the CFC-ozone issue NASA is charged with developing and carrying out a comprehensive program of research, technology, and monitoring of the phenomena of the upper atmosphere so as to provide for an understanding of and to maintain the chemical and physical integrity of the Earth's upper atmosphere. The NASA research program is closely coordinated with related research programs in NOAA and NSF, as well as research programs conducted abroad. A comprehensive research program has been developed by these scientific agencies in concert with the scientific community. While the program is responsive to the short term needs of the policy-makers, it also recognizes the need to study more speculative and complex aspects of the issue deemed to be scientifically important.

NASA was also charged with providing biennual reports to the Congress and concerned regulatory agencies on the status of upper atmospheric research, including scientific assessments of potential effects of human activities on the atmosphere, and particularly, on stratospheric ozone. Since 1980 the scientific assessments have been cosponsored with other US scientific agencies (NOAA and FAA) and international scientific agencies such as the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP). The scientific assessments have been written by the best scientists in the world. The decision not to write national scientific assessments but to write international scientific assessments was a vital element in the successful development of the Montreal protocol. The international ozone assessments have been heralded by both scientists and policy-makers as an essential component of the development of both science (identifying areas of scientific uncertainty) and policy. It was essential that all nations used the same scientific basis for policy formulation. However, in hindsight, it is clear that improvements can be made in the formulation of the future ozone assessments, namely by:

* (a) participation from certain key countries including the USSR, Japan, China, and India; and

* (b) greater exchange between the scientists involved in the preparation of the scientific assessment and the policy-makers.

Climate Change:

In order to understand what initiates changes in climate requires an understanding of the forcing functions of the system, and predicting the magnitude and timing of the climate change requires an understanding of the planetary response processes. In addition, it essential to understand the consequences of climate change. An understanding of the magnitude, timing, and consequences of climate change is needed for formulating policy response strategies.

Why is an Accurate Prediction of Climate Change Important?

An accurate prediction of climate change is important because of the potential impacts on society and how domestic and foreign policies of the United States Government and industry might be influenced. The consequences of climate change which need to be understood include:

(1) how will the spatial and temporal distribution of precipitation and temperature change?
(2) how will the frequency and magnitude of severe weather change, e.g. cyclones, tornados, droughts, floods, etc.,
(3) how will the productivity of agricultural (crops and forests) ecosystems change?
(4) how will the areal extent and productivity the of natural (grasslands, tundra, wetlands, and forests) ecosystems change?
(5) what will be the rate and magnitude of sea level change?
(6) what will be the direct and indirect consequences on human health?
(7) how will water resources be affected?
(8) how will the utilization of natural resources be impacted?.

It can be seen from the above list of potential consequences of a change in climate that the possible impacts on society are important. Energy, agricultural, natural resource, coastal zone management, and water resource policies will all be influenced by a change in climate? For example, if we want to understand how changes in the physical climate system (temperature, precipitation, frequency and magnitude of severe weather) will impact agricultural and energy policies we need to improve our scientific knowledge of ecosystem response to changes not only in climate parameters, but other ecological stress factors that might change in the same time period.

What Scientific Knowledge is Required to Accurately Predict Future Climate States?

(i) What Initiates Climate Change?

It is clear that we must improve our quantitative understanding of what initiates climate changes. The forcing functions of the climate system are both natural and anthropogenic. The natural forcing functions include: (i) changes in solar irradiance, and (ii) changes in the chemical composition and aerosol content of the atmosphere because of evolutionary and volcanic processes. Anthropogenic forcing of the climate system includes: (i) increasing the atmospheric abundances of trace gases such as carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), oxides of nitrogen (NO_x), and halocarbons (CFCs and Halons) which alter the Earth's radiative balance through the so-called greenhouse effect, and (ii) changes in land use and cover.

Natural Changes

Stratospheric aerosols are believed to affect the climate significantly only when there is substantial enhancement resulting from a volcanic eruption. The stratospheric aerosol layer that remains after a major volcanic eruption has been found to increase stratospheric temperatures by several degrees and tropospheric temperatures are, by the best estimates, lowered by several tenths of a degree due to the effect of the aerosol layer on the solar and infrared radiation fields. Thus, the stratospheric aerosol parameters do have a strong impact on the radiation field and on climate. Since the stratospheric aerosol layer is formed in situ from gases emitted during the eruption, it is necessary to monitor changes in atmospheric composition due to volcanic erruptions and to study the photochemical interactions and feedbacks involving volcanic gases.

It is essential to improve our understanding of the short (27 day solar rotation) and long-term (11 / 22 year sunspot cycles) variability in the output of the sun, both total irradiance and flux as a function of wavelength. Solar variability is a major contributor to natural changes in the radiative balance and the chemical composition of the atmosphere. Hence, it is important to monitor, and understand the impact, of solar variabilty on the climate system.

Anthropogenic Changes:

There is now compelling observational evidence that the chemical composition of the atmosphere is changing at a rapid rate on a global scale (see Table 1). The atmospheric concentrations of CO_2, CH_4, N_2O, and CFCs 11 and 12 are currently increasing at rates ranging from 0.2 to 5.0% per year. These changes in atmospheric composition reflect in part the metabolism of the biosphere and in part a broad range of human activities, including agricultural and combustion practices.

It is widely recognized that one of our greatest difficulties in accurately predicting future changes in climate is our inability to predict the future evolution of the atmospheric concentrations of water and other radiatively active gases. An understand is needed of the role of the biosphere in the hydrological cycle and in regulating the emissions of gases such as CH_4, CO_2, N_2O, and methyl chloride (CH_3Cl) to the atmosphere. We also need to know the most probable future industrial release rates of radiatively and chemically active gases such as the CFCs, Halons, N_2O, CO, CO_2, hydrocarbons, and the oxides of sulfur and nitrogen which depend upon economic, social, and political factors. Also needed is an understanding of how land use practices will change as societies continue to develop.

Although the rates of change of the trace gases are well documented, the underlying reasons for the changes are not. For example, the increasing atmospheric concentrations of methane may be due to an increase in the fluxes of methane from one or more of the sources, or a decrease in the atmospheric removal rates of methane. Methane is produced in anaerobic environments, including rice paddies, natural wetlands, enteric fermentation in cattle and termites, and biomass burning, and is removed in the troposphere by reaction with hydroxyl radicals. Numerous explantions have been proposed to explain the increasing abundance of methane including, the increased production of rice, the number of head of cattle, an increase in the outgassing of methane from the tundra because of climate warming, and that the concentration of tropospheric carbon monoxide is increasing causing a decrease in the concentration of the troposheric hydroxyl radical which controls the abundance of methane. Consequently, it is essential to improve our current understanding of the geophysical and biological processes that control the transfer of these trace gases into and out of the atmosphere from the aquatic and terrestrial biosphere. This will require an improved understanding of the processes which control the fluxes of gases such as methane into and out of ecosystems, and precise knowledge of the areal extent, and rate of change of areal extent, of the relevant ecosystems.

Presently, and in the near future, changes in the concentrations of trace gases other than CO_2 are thought to be contributing to the greenhouse warming of the Earth's surface and lower atmosphere by an amount that is about equal to that due to changes in the concentration of CO_2. The cumulative effect of the increase in all trace gases for the period 1850 to 1980 is a predicted equilibrium warming (this neglects the heat capacity of the oceans) in the range 0.7 to 2.0^0K, about half of which should have occurred to date. Model calculations indicate that the greenhouse warming predicted to occur during the next 50 years should be about twice that which has occurred during the previous 130 years, i.e. an equilibrium warming of between 1 to 5 degrees Centigrade. The warming is predicted to be greatest at higher latitudes, especially in winter, a factor of 1.5 to 3 times greater than the predicted warming at equatorial latitudes. The key issues are the magnitude and timing of the predicted global warming. The magnitude is not only sensitive to the rate of change of the atmospheric abundances of the trace gases, but also depends upon future changes in cloud cover and distribution. The timing of the warming is largely controlled by the rate at which the oceans and atmosphere equilibrate.

One important aspect of the global warming issue is that the atmospheric lifetimes of gases such as N_2O, CO_2, $CFCl_3$, and CF_2Cl_2 are known to be very long. Consequently, if there is a change in climate caused by increasing atmospheric concentrations of these gases the full recovery of the system will take several tens to hundreds of years after the emission of these gases into the atmosphere is terminated.

(ii) How Does the Planet Respond to Changes in Climate Forcing Functions?

The sun provides the basic source of energy that drives the circulations of the atmosphere and oceans. Both the incoming solar and outgoing terrestrial radiation are affected by factors such as clouds, trace gases, aerosols, and surface reflectivity, as well as by processes that take place on the sun. The residual energy in the earth's atmosphere, oceans, and land and ice masses, its transport, and its variations with time force the entire range of atmospheric and oceanic motions, and produce convection, clouds, and storm systems. These constitute the weather, and when aggregated over time, constitute climate.

Understanding the basic nature of solar and earth radiation and its transfer through the atmosphere to and from the land surfaces and oceans is one of the fundamental goals of climate research. Monitoring and analysis of the sun and components of the earth's radiation budget are crucial to developing this understanding. They will be used to diagnose the present (and near-future) state of the climate, for the formulation of empirical prediction techniques, and ultimately for the development and validation of global and regional climate prediction models. Insights gained in studying the earth's radiation budget are also vital to developing confidence in prediction of the long-term effects of anthropogenic influences such as CO_2, ozone, other radiatively active trace gases, and aerosols, as well as the effects of natural phenomena such as volcanic eruptions.

To understand climate one must understand the processes by which the atmosphere, oceans, cryosphere, land surface, and vegetation exchange energy, momentum, and moisture. Of all the exchange processes, radiative energy has a special role in climate because the energy balance of the total climate system is dependent upon the exchange of the earth's radiation energy with its surroundings (specifically, it is a balance between the energy absorbed from solar illumination and the energy lost to space by thermal emission). Furthermore, the non-uniformity in the global distribution of net energy balance at the top of the atmosphere represents a pattern of sources and sinks of energy which drive the atmospheric and oceanic circulation and determine the world-wide distribution of wind, temperature, and humidity. The vertical distribution of sources and sinks within the atmosphere is determined by the radiative properties of the atmosphere and surface. Of particular importance is the partition of radiation energy between atmosphere and oceans. This energy partition sets up the process in which the oceans become the buffer for climate change. In some seasons the oceans store energy, while in other seasons they supply energy to the atmosphere. In any event, the oceans play as important a role as the atmosphere in the global redistribution of excess energy from low latitudes, and the radiation budget at the surface is directly involved in this process.

The radiation field appears in many aspects of the climate problem. Indeed, the complexity of the climate system is in large part due to the existence of non-linear feedback processes which connect the radiation field to just about every component of the climate system. To the extent that these processes are important, radiation plays a pivotal role in determining the response of the climate system to any perturbation.

There are a number of planetary response processes, i.e. how the climate respond to changes in the forcing functions, which need to be understood in order to predict the magnitude and timing of changes in the Earth's climate. These include:

(1) the water vapor greenhouse feedback---as climate changes how will the atmospheric abundance of water vapor change? An increase in atmospheric temperature would lead to an increase in water vapor which, in turn, leads to increased absorption of solar radiation and reduced loss of thermal radiation to space; the consequent increase in net energy input then causes a further increase in temperature.

(2) the ice-albedo feedback---as climate changes to what extent will the spatial and temporal distribution of ice change, hence change the local surface albedo, and in turn impact upon the radiative balance of the atmosphere? An increase in surface temperature will, in general, reduce ice and snow cover, the consequence of which is an increase in net solar energy input, which will lead to a further increase in temperature.

(3) the cloud-albedo feedback---as climate changes how will the spatial and temporal distribution of clouds change and influence the radiative balance of the atmosphere by reflecting incoming solar radiation and trapping outgoing terrestrial radiation ? The problem is complicated in that different types of cloud have different effects on the solar and thermal infrared components of the radiation field. Since clouds generally cause a decrease both in absorbed solar energy and in thermal emission to space, the net effect of a particular cloud type can be either to increase, decrease, or leave unchanged the net energy

in a vertical column. It is for this reason that heavy emphasis is placed on clouds in climate-related studies.

(4) aerosol - cloud interactions---can changes in climate alter the atmospheric abundance of trace gases such as DMS which in turn might alter the aerosol content of the troposphere thus possibly influencing the extent and distribution of clouds? There has also been some speculation concerning a feedback involving tropospheric aerosols and soil moisture. Reduced precipitation and dry soil can lead to an increase in the level of tropospheric aerosols, which might alter the atmospheric circulation by their effect on the radiation field - either directly or by their influence on cloud formation.

(5) ocean - atmosphere interactions:

(a) heat capacity - ocean circulation---what controls the rate of exchange of energy at the ocean-atmosphere interface, and will it alter with a change in climate? Will ocean circulation and the marine ecosystems be impacted by a change in climate, and how would this influence the uptake and release of carbon dioxide and other climatically or biologically important species?

(b) sea surface temperature - atmospheric circulation - precipitation---how will atmospheric circulation and precipitation patterns respond to a change in sea surface temperatures, and vice-versa?

(6) land (soil and vegetation) - atmosphere interactions---how will the productivity and areal extent of terrestrial ecosystems and soils be influenced by changes in climate, and how will changes in these ecosystems influence the climate system by altering the exchange of energy and water between the atmosphere and the terrestrial ecosytem?

(7) trace gases and the biosphere: sources and sinks---how will a change in climate alter the geophysical and biological processes that control the fluxes of trace gases, which directly or indirectly affect the radiative balance of the atmosphere?

(8) atmospheric chemistry---as the trace gas composition of the troposphere changes how will this influence the atmospheric lifetimes, hence abundances, of radiatively active trace gases (greenhouse gases, e.g. methane, tropospheric ozone, etc) in the troposphere which will in turn affect the radiative balance of the atmosphere? As the trace gas composition of the troposphere changes how will the chemistry of the stratosphere respond (e.g. abundance and distribution of ozone), and how will a change in statospheric composition affect the radiative balance of the atmosphere, atmospheric circulation, and the exchange of energy and chemicals from the troposphere to and from the stratosphere?

While each of the planetary response processes has been discussed in terms of how the process might respond to a changing climate it should be recognized that in most cases there are significant scientific uncertainties as to how the processes operate today.

How Can We Test Our Capability To Predict Changes in Climate?

Quantitative predictions of past, present, and future climate states from changes in forcing functions requires the development of multi-dimensional models to describe, or parameterize, the planetary response processes. The validity of such models can be tested against the past climate record and observations of the contemporary atmosphere. The key questions to be asked include:

(1) How well do our climate models describe the long-term record of past responses (paleoclimate) to climate forcings? This can be used, within limitations, to test, the ability to rationalize cause and effect on timescales of decades to centuries.

(2) How well do our climate models simulate the observed seasonal cycles and biennial oscillations in a number of climate parameters?

(3) How well do our climate models simulate how climate responds to episodic events such as El-Nino and volcanic injections of gases and particulate matter? This type of test can be used to test our understanding of specific planetary response processes such as whether the observed changes in lower stratospheric temperatures after the erruption of El-Chichon are consistent with the predictions of local heating rates based on the calculated amounts of infra-red radiation absorbed by sulfuric acid droplets.

What Specific Research Questions Need to be Addressed?

It is clear that while significant progress has been made in our understanding of the physical, chemical and biological processes that control the climate system, and the consequences of a changing climate, significant uncertainties remain. The Antarctic ozone phenomenon vividly demonstrates that the environment does not always change slowly, linearly, or predictably in response to a perturbation. In fact, one key question is whether the climate system can have multiple states?

Therefore, improving our ability to predict climate and understand the consequences of a changing climate will require a comprehensive research program with research being conducted in many areas. NASA is presently doing research to reduce our current scientific uncertainties as described below:

NASA Research Programs Related to Global Change:

The principal activities that comprise nearly all research programs include: (1) the development and deployment of satellite-based observing systems; (2) the collection, processing, and analysis of satellite observations; (3) the development and application of techniques for extracting parameters from remote (satellite-based) measurements; (4) field experiments, where observations are made from surface, aircraft, and balloon platforms, usually to validate or support the satellite observations or technique development activities; (5) process oriented studies; (6) the theoretical analysis and numerical modelling of physical processes affecting climate; and (7) archiving and disemination of data and information.

A vital component of a National Climate research program is the utilization of space technology to understand the processes which control the earth's climate system and its sensitivity to natural and man-induced changes and to assess the possibilities for climate prediction on time scales of from about two weeks to several decades. Because the climate is a complex multi-phenomena system, which interacts on a wide range of space and time scales, the diversity of scientific problems addressed requires a hierarchy of models along with the application of modern empirical and statistical techniques which exploit the extensive current and potential future global data sets afforded by space observations. Observing system simulation experiments, exploiting these models and data, will also provide the foundation for the future climate space observing system.

Major international planning is underway concerning characterizing the nature of cloud-radiation feedback and on understanding the role of the oceans as a thermal buffer and major source of internal climate variability. Other important research involves the planetary boundary layer processes, particularly with regard to tropical energetics and latent heat transport to extra-tropical regions. Progress in the latter is dependent on the improvement of coupled ocean-atmosphere models, first with the ocean mixed layer for short-range problems such as the El Nino phenomenon, and subsequently with the deep ocean for studies of long-range climate change.

Equal emphasis should be given to both short-range and long-range climate studies, and the corresponding need for developing improved modeling tools. Short-range (seasonal and interannual) climate fluctuations which have obvious connections to certain extreme anomalies such as the recent El Nino event (1982-1983) and the El Chichon volcanic eruption (1982) must be understood to evaluate existing skill for climate prediction and thus carry a high priority in modeling research. Understanding the long-range (decadal to 50 or more years) climate impact of natural and man-induced changes is viewed to be of similar priority. Indeed, virtually all processes which have a bearing on the long-range prediction problem play some role in the corresponding shorter-range problem and are relevant for current study.

Information contained in the global data sets acquired by remote sensing from satellites can provide a unique resource for defining initial state and boundary conditions for model experiments, serve as a factor in model output verification, and provide valuable insight into subtle relationships and teleconnections among climate variables, which can then be explored in detail with the sophisticated numerical models.

(1) Atmospheric Chemistry

A. The Upper Atmosphere Research Program

The long-term objectives of the NASA Upper Atmosphere Research Program are to perform research to:

(1) understand the chemical, dynamical, and radiative processes that control the physical structure and chemical composition of the Earth's upper atmosphere, and

(2) accurately assess possible perturbations of the upper atmosphere caused by human activities.

Specifically, of greatest urgency at present is an assessment of the combined effects of continued increases in the atmospheric concentrations of carbon monoxide (CO), carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), oxides of nitrogen (NOx), and halogen containing gases such as chlorofluorocarbons 11, 12, 113 and methylchloroform (CH3CCl3), Halons 1211 and 1301 on atmospheric ozone and the climate system. Our knowledge of the key physical and chemical processes controlling the chemical composition and structure of the upper atmosphere has advanced significantly during the last few years. However, we must recognize that significant uncertainties in our knowledge still remain and can only be resolved by a vigorous program of research. NASA is committed to continuing its leadership role in studying the upper atmosphere and working closely with the university and non-university scientific community; other U.S. government agencies, in particular the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), the Environmental Protection Agency (EPA), and the Federal Aviation Administration (FAA); industry, i.e. the Chemical Manufacturers Association (CMA); and other national and international scientific agencies, e.g. the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP), to resolve these outstanding uncertainties in an expeditious manner.

NASA's program is broad and comprehensive and its research activities generally fall into three general categories:

(1) Field Measurements and Technology Development:

This activity consists of studying the geographic distributions and strengths of trace gases released at the Earth's surface, measuring the solar irradiance incident on the Earth's atmosphere, determining the chemical composition and physical structure of the atmosphere using a balanced set of in-situ and remote sensing techniques, and the development of instrumentation. A wide range of instruments are currently being utilized on a variety of platforms including aircraft, balloons, rockets, space shuttle, and satellites. Ground based observations are also performed. The principal objective of the field measurements program is to provide a description of the composition and structure of the atmosphere which can be used as a test of the theoretical models. These field and satellite programs will overcome our greatest shortcoming which is that we are presently data limited. The most important recent development in our knowledge of the chemical composition and structure of the stratosphere has been the analysis validation and release of data obtained by instruments flown on the Nimbus 7 (the Limb Infrared Monitor of the Stratosphere (LIMS), the Stratospheric and Mesospheric Sounder (SAMS), and the Solar Backscatter Ultraviolet/Total Ozone Monitoring System (SBUV/TOMS)), Applications Explorer II (AEM-2) (the Stratospheric Aerosol and Gas Experiment (SAGE), and Solar Mesospheric Explorer (SME) (visible and infrared spectrometers) satellites, and on the Space shuttle (the high resolution ATMOS infrared interferometer). This data is currently undergoing further intensive interpretation.

(2) Laboratory Studies:

Laboratory measurements are carried out to provide the basic input data for the theoretical models. These data consist primarily of chemical kinetics rate constants and photochemical cross-sections. In addition, spectroscopic data of atmospheric constituents are acquired for the interpretation of atmospheric measurements. Development of calibration standards is also a vital aspect of this program.

(3) Theoretical Studies and Data Analysis:

The two principal activities in this area of the program are the development of a hierarchy of models to describe the chemical, radiative, and dynamical processes which control the chemical composition and physical structure of the present atmosphere and to predict possible future changes, and the analysis and interpretation of large satellite data sets and other major field measurement campaigns.

Some specific thrusts in the near term include:

(1) A vigorous effort to understand the processes responsible for the observed decrease in the ozone column above the Arctic in winter. This effort is strongly supported by the NOAA, NSF, and by the CMA. An aircraft and ground-based field measurement campaign for January / February 1989 is being planned. NASA is planning to base two aircraft, an ER-2 with an altitude ceiling of 21 kilometers and a DC-8 with an altitude of 13 kilometers, containing approximately 16 state-of-the-art in situ and remote sensing instruments at Stavanger, Norway for a six week period starting about January 1, 1989.

(2) The final design and initial implementation of "A Network for the Detection of Stratospheric Change." This network is being designed to provide the earliest possible detection of changes in the chemical composition and physical structure of the stratosphere, and the means to understand them. Successful implementation of this system will require cooperation and coordination at both the national and international level. Discussions on the implementation of this system with NOAA and the Chemical Manufactures Association are currently in progress.

(3) The Upper Atmospheric Research Satellite (UARS), for which the launch date is uncertain due to Challenger manifest changes but is currently scheduled for 1991, will provide the first simultaneous measurements of the atmospheric distributions of oxygen, hydrogen, nitrogen, and chlorine species, coupled with measurements of temperature, dynamical quantities such as winds, and energy inputs and losses. These measurements will allow us to study the coupling between the chemical, radiative, and dynamical processes which control the chemical composition and structure of the stratosphere, and, in particular, the amount and distribution of ozone, in a manner never before possible, the mechanisms responsible for atmospheric variability, and the response of the stratosphere to changes in external factors such as solar activity and natural phenomena such as volcanic eruptions.

(4) Atmospheric concentration measurements and flux measurements of biogenic gases predicted to control atmospheric ozone from representative ecosystems in order to understand past and future trends in the composition of the atmosphere. Particular emphasis is on methane, which also plays an important role as a greenhouse gas.

5) The continued development of theoretical models which can simulate the coupling between the chemical, radiative, and dynamical processes that control the chemical composition and structure of the atmosphere.

These research activities are ongoing, multiyear efforts aimed at reducing some of the current uncertainties in our scientific understanding of these issues. We expect that progress in most areas will be steady and that many of the key uncertainties should be significantly reduced within a decade. We expect very significant progress on the issue of Antarctic ozone within a few years, but understanding the coupling between the chemical, radiative, and dynamical processes that control the chemical composition and structure of the atmosphere will require the UARS data before much more progress is made. If the "Network for the Detection of Stratospheric Change" is implemented, then significant progress on detecting and understanding the causes of changes in stratospheric composition should be expected within a decade. But a fuller understanding of the factors which control atmospheric ozone will require a new initiative in the Earth sciences because the ozone issue is not simply a problem of understanding the atmosphere, but requires an intimate knowledge of the oceans and land.

B. The Tropospheric Chemistry Program:

The goal of the tropospheric chemistry program is to develop an understanding of global tropospheric chemistry and assess the susceptibility of the global atmosphere to chemical change. Tropospheric chemistry plays an extremely important role in biogeochemical cycles, governing (in conjunction with dynamical processes) the concentration distribution of atmospheric trace species and altering the chemical composition in which trace elements move through the atmosphere. It is a crucial science in the evaluation of the effects of atmospheric chemical change on the global hydrological cycle, the cycling of nutrient compounds through the environment, the accumulation of infrared active gases in the atmosphere, the acidity of rain and snow, and the depletion of ozone in the upper atmosphere by chemical species that have their sources and sinks in the troposphere.

The objectives of the NASA Tropospheric Chemistry Program are to:

(1) Develop techniques for remote and in situ measurement of the concentrations and fluxes of key tropospheric species

(2) Determine tropospheric meteorological/chemical influences on the atmosphere as a whole, particularly the stratosphere;

(3) Understand the chemistry of global tropospheric species and the causes of changes in chemical composition;

(4) Develop a realistic general circulation model of the global troposphere with chemistry included for use in field experiment design and data analysis;

(5) Develop and implement a strategy for chemical measurements from space platforms.

Measurements of the most important chemical species involved in global biogeochemical cycles require instruments capable of operating in the parts per trillion range (for NOx) and even the parts per quadrillion range (for HOx) against the natural atmospheric background and on aircraft and/or at complex ground sites as diverse as the tropical rain forest and the arctic tundra. For flux measurements by eddy correlation a time response of 10-20 Hz is required for boundary layer experiments, and a time response of 1 - 2 Hz is required for experiments on troposphere/stratosphere exchange. Development of the capability to meet these measurement needs is a major task and a crucial one for future progress.

Projects aimed at instrument development are being done within the NASA program concurrently with field programs that utilize available instruments to study atmospheric chemistry in environments of prime interest, such as the tropics, agricultural wetlands, and the troposphere/stratosphere interface. In many cases the instruments involved in the central experiments in the field projects are the results of the instrument development and validation elements of the NASA program.

In order the achieve the program's goal fairly large scale field projects must be carried out within the next decade. To conduct these experiments in the most efficient manner a general circulation model is required, and is under development, to provide a calculation of the large scale dynamical processes that transport reacting and non-reacting species through the atmosphere. This model should allow for inclusion of such processes as chemistry inside clouds and the role of cloud chemistry in transporting chemicals within the atmosphere. It would serve as a tool for planning the optimum field experiments and synthesizing the data from them. Simpler, one and two dimensional models with parameterized transport are also under development and refinement to aid in field experiment design and analysis.

The current program elements are designed to support directly the goals and objectives described in the preceding section. they are as follows:

(1) Modeling and Data Analysis - supports the continued development and application to experiment planning and data analysis of 1- and 2D photochemical models with parameterized transport and the development of a general circulation model with chemistry included.

(2) Field Measurements - Supports field measurements with existing, proven instrumentation and necessary improvements to research platforms to carry out field measurement and instrument intercomparison projects. These field measurements have been collectively named the Global Troposphere Experiment (GTE) and constitute the major thrust of the program. They are organized into Atmospheric Boundary Layer Experiments (GTE/ABLE) and Chemical Instrumentation Test and Evaluation (GTE/CITE) projects.The first group focus on source/sink studies, while the second focus on instrument development and validation. Addition of an exploratory series aimed at tropical chemistry and transport is planned.

(3) Laboratory Studies - Supports a small effort in homogeneous, gas-phase chemical kinetics and laboratory work aimed specifically at measuring energy transfer cross sections and spectroscopic constants needed by some of the higher technology instruments under development.

(4) Instrument Development - Supports research aimed at developing the instruments needed to meet the measurement goals of the program.

The current program thrusts are:

(1) A GTE/CITE-3 sulfur species and ammonia intercomparison experiment to be conducted from Natal, Brazil in 1989 to build upon the highly successful CITE-1 and CITE-2 experiments that intercompared instruments to measure OH, CO, and several nitrogen species at concentration levels found in the clean troposphere;

(2) Analysis of the CITE-2 data on odd nitrogen species to determine the abundances and partitioning of the major reactive nitrogen species in the continental and remote oceanic troposphere;

(3) Analysis of the rich data base acquired in the highly successful ABLE-2A and ABLE-2B experiments in Brazil in 1985 and 1987 to obtain quantitative information about the sources and sinks for important trace gases and aerosols located in the tropical rain forest and investigate the causes of high CO concentrations off the coast of Brazil observed in two shuttle flights. The expeditions, which involved aircraft, instrumented towers, tethered balloons, and boats on the Amazon River were the largest ever mounted to study the atmospheric chemistry of the Amazon Basin.

(4) Development of second generation OH detection instrument with sufficient sensitivity for global measurements from aircraft.

(5) Limited enhancements in heterogeneous chemistry in laboratory and field measurements.

(6) Continued discussion with the People's Republic of China about a joint boundary layer experiment over agricultural wetlands in China;

(7) Planning for a DC-8 based series of experiments over the tropical Atlantic and Pacific Oceans to follow the distribution of gases from the Amazon Basin and the ocean upwelling region off the coast of Peru, the latter mission to be preceded by intensive studies of the source strength of the upwelling with the NASA Electra in a GTE/ABLE-4 project

Tropospheric chemistry offers an opportunity for major progress in understanding the stratosphere, understanding biogeochemical cycles, buildup of infrared gases in the atmosphere, and significant breakthroughs in remote sensing when enhanced funding is found to accelerate the pace of the critically needed instrumentation, the science and technology needs for which have been well developed in a series of NASA planning workshops. Enhanced funding would also allow increase in the scope and frequency of expeditionary field experiments, such as GTE/ABLE and GTE/TRACE, and a great improvement in long-term monitoring activities. The NAS/NRC has recommended that a major international program in tropospheric chemistry be undertaken that would require strong participation by NASA, NSF, and NOAA. Current coordination among these agencies is already quite strong, providing a good basis for enhanced programs in tropospheric chemistry in all three agencies, each of which brings unique capabilities to the overall program.

(2) Climate Research Program:

The long-term objective of the NASA Climate Research Program is to conduct research to improve our understanding of the radiation and dynamical processes which govern the climate system of the Earth and to observe the physical properties of the system which influences its change. The unique aspect of the NASA program is its use of space technology to address these objectives. The program includes research on: establishing the long term data base required for climate studies; analyzing the data base; developing models to diagnose and describe the climate system; and developing special observing capabilities to address problems unique to climate.

Understanding the basic nature of solar and Earth radiation and its transfer through the atmosphere to and from the land surfaces and oceans is one of the fundamental goals of climate research. Monitoring and analysis of the sun and components of the Earth's radiation budget and their effects on the atmosphere, land and oceans are crucial to developing this understanding. They will be used to diagnose the present (and near future) state of the climate, for the formulation of empirical prediction techniques and, ultimately, for the development and validation of global and regional climate prediction models. Insights gained in studying the Earth's radiation budget are also vital to developing confidence in prediction of the long-term effects of man's influences such as CO2, ozone, and aerosols, as well as the effects of natural phenomena such as volcanic eruptions.

Recognizing the importance of this research in improving our understanding of the mechanisms controlling climate variations, the National Climate Program has established a principal thrust in Solar and Earth Radiation and has assigned NASA lead agency responsibilities for organizing and conducting a long-term broad-based research program of observations and analysis. The broad nature of this activity has required close coordination with other federal agencies having overlapping programmatic interests, in particular NSF, NOAA, and DOE, as well as with the international scientific community through the World Climate Research Program.

Recent precise measurements from the NASA Solar Maximum Mission (SMM) and the Nimbus-7 Earth Radiation Budget (ERB) experiment have established that the total solar radiation flux, also known as the "solar constant," above the atmosphere is indeed variable. Since 1979, sensors on both spacecraft independently observed variations of the solar flux as large as 0.25 percent on time scales from days to weeks. The amplitude of observed monthly and yearly variations, although smaller, nevertheless have the potential for affecting climate and, as such, are high priority monitoring objectives. Additional data are now becoming available from the NASA Earth Radiation Budget Experiment (ERBE), which also confirm the observed solar flux variability. Future plans are to incorporate a similar instrument on the Upper Atmospheric Research Satellite (UARS), which will continue these measurements into the 1990's. Periodic Shuttle sortie flights are planned to verify the performance of the free-flyer measurements and to intercompare other instrument designs.

The study of the role of clouds in climate has been given a particular emphasis in NASA-sponsored climate research. Clouds have a very strong modulating influence on the radiative energy exchange between the atmosphere and the upper and lower boundaries. They control the amount of solar energy absorbed by the climate system as well as the longwave energy radiated to space. The partitioning of the solar energy input between the atmosphere and oceans is also highly dependent upon cloud cover. These effects are extremely important on climate time scales and are critical to our understanding the effects of long-term CO2 building in the atmosphere.

The first step necessary in understanding the role of clouds is to develop a climatology of the important cloud parameters over a period which reveals the diurnal, seasonal, and interannual variations. This requirement is being met through NASA's central role in the International Satellite Cloud Climatology Project (ISCCP), organized as a part of the World Climate Research Program (WCRP). The ISCCP, which began in 1983, routinely collects and processes cloud image data from the international array of operational meteorological satellites operated by the U.S., Japan, India, and the European Space Agency, to produce a five-year global cloud data set.

It is also essential to develop cloud models which incorporate the basic physical processes which contribute to the generation, maintenance and dissipation of clouds. In order to gather the data to test these cloud models, NASA, along with NSF, NOAA, and DOE, is conducting a series of field experiments in which the relevant atmospheric and cloud parameters will be measured in detail over a number of cloud formation cycles and a variety of synoptic weather conditions leading to the generation of various cloud types. This effort is a part of the First ISCCP Regional Experiment (FIRE) which began in 1987 and will continue through 1989.

Whether viewed as part of the WCRP, or as basic elements for the proposed International Geosphere/Biosphere Programs, these experiments will not only benefit oceanography and climate, but will also make fundamental contributions to Earth Science. In addition, the understanding gained from these experiments will assist in the design of future operationally oriented ocean and climate observing systems.

(3) Oceans Research Program:

Two recent events have emphasized the ocean's importance in global climate: the disastrous 1982-1983 El Nino, which caused billions of dollars in damage and considerable loss of life, and the potentially harmful effects of increasing CO2 levels in the atmosphere due to the burning of fossil fuels. We now know that our ability to understand and ultimately predict the droughts and flooding associated with a severe El Nino or with the warming predicted from a CO2 increase is severely limited by a lack of ocean measurements. New global information available from satellites, coupled with data from the interior of the ocean, will meet this need.

Reports from the National Academy of Sciences and studies by various government agencies all point to the serious consequences of a global warming. They also stress the need for better understanding of the problem, particularly the role of oceans and ice cover in either modulating or amplifying the warming trend. The existing climate models used for predicting carbon dioxide induced warming oversimplify interactions between the atmosphere and the ocean. Any significant improvement will require many more observations leading to a better understanding of oceanic and atmospheric behavior.

For the oceans, the crucial measurements include ocean circulation, sea surface winds and temperatures, biological productivity, and the polar ice cover. Biological productivity can be determined through measurements of ocean color, which depends primarily on the photosynthetic pigments (chlorophyll) contained in marine plants. Since these plants are the basis of the marine food web, measurements of their amount and distribution are critical to obtaining a better understanding of biological and chemical processes, including the cycling of carbon through the oceanic ecosystems. All of these measurements should be well distributed over the globe and made regularly to determine natural variability. Such coverage can be provided only from a space-based program operating over a period of several years.

NASA plans for the decade of the 1990's include the flight of a scatterometer (for sea surface winds) aboard the Japanese ADEOS satellite; a dedicated altimeter mission for ocean currents, the Ocean Topography Experiment (TOPEX), and a color scanner (for ocean biological productivity) aboard a platform of opportunity. In order to exploit the potential offered by this next generation of oceanographic sensors, we are working with the NSF, U.S.Navy, and NOAA, as well as with our international partners to plan a set of comprehensive at-sea experiments. Two examples are the Tropical Ocean Global Atmosphere and World Ocean Circulation Experiments being organized under the World Climate Research Program (WCRP).

(4) Land Processes:

It is well known that climate fluctuations and trends may have effects on society--on a regional as well as on a global scale. Land observations from satellites will also become part of a data base for monitoring changes of the surface, for instance of vegetation and snow cover, and of the climate of the surface of the earth. Such monitoring is particularly urgent at the present time due to man's increasing sensitivity to climatic fluctuations and the possibility that man's activities may have climatic consequences.

As stated earlier, the continued burning of fossil fuels may lead to increases in atmospheric carbon dioxide large enough to have a significant global climate impact. Changes in agricultural practices may lead to regional desertification or deforestation, which can lead to regional changes in the energy and moisture budgets. Draining wetlands can cause large changes in methane production, another important gas related to global temperature changes. It is clear that global, continuous monitoring of such anthropogenically induced changes, as well as naturally occurring variations, can only be obtained from satellites.

NASA is encouraging the development of the International Satellite Land Surface Climatology Project to develop methodologies for deriving quantitative information concerning land surface climatological variables from satellite observations of radiation reflected and emitted by the earth. Such quantitative information is required to:

(1) Monitor global scale change of the land surface caused by climatic variations or by human activity;

(2) Further develop mathematical models designed to predict or simulate climate at various time scales;

(3) Permit inclusion of land surface climatological variables in diagnostic and empirical studies of climate variations.

The time is appropriate for conducting such studies because of the increasing sophistication both of remotely sensed observations from space and the development of improved climate and medium range weather prediction models.

The land surface variables of interest and potentially obtainable more or less directly from satellite observations are vegetation cover, albedo, solar radiation, longwave radiation, skin temperatures, emissivity, soil moisture, and snow cover and depth. The work may be divided into two parts:

(1) Evaluation of existing satellite data collected in the last fifteen years to determine their usefulness in detecting climate related fluctuations or man-induced changes in the surface of the Earth.

(2) Development and validation of methods to convert satellite-observed radiances to surface climatological variables. The validation effort will require intercomparison of satellite-derived quantities with simultaneous ground- and aircraft-based measurements, to be carried out in field programs in selected areas.

The first investigators in the first part of this work, retrospective studies, were selected in response to a letter issued in January 1985. The first field experiment was held at the Konza Prairie Grassland in Kansas in 1987. This site is managed by Kansas State University in conjunction with the National Science Foundation.

An experiment with somewhat similar aims was conducted in France in the summer of 1986 under the auspices of the World Climate Research Program. NASA sent a C-130 aircraft equipped with various radiometers for remote sensing for a six week period during this experiment. NASA also assembled a team of investigators from NASA, USDA, and various universities to analyze the resultant data.

The land surface climatology work being led by NASA should lead to important new insights as to the interactions between the land and the atmosphere, and thus of how the Earth functions as a global system.

(5) Interdisciplinary Research Program:

NASA established an Interdisciplinary Earth Science Research Program in 1984. Three areas of research were chosen for an initial three year study representative of the kind of research that needs to be performed in a Global Change program. These were particularly important areas of research in which progress could be made. The three areas were:

(1) a program of research to understand the reasons for the increasing trend in the atmospheric concentration of methane, and the long-term consequences of it for climate and ozone if it continues;

(2) a land-surface climatology program which is aimed at determining the extent to which changes are taking place in climatologically important properties of the land surface, to quantify those changes in physical and biological terms, to determine the important processes which control the changes, and to determine the overall stability of the land-climate system; and

(3) an ocean basin scale carbon flux program which will develop a better understanding of the magnitude, variability, and fate of carbon fluxes in th oceans on an ocean-basin scale, and the role of oceanic carbon fluxes in global scale biogeochemical cycles and climate.

Three new areas of research have evolved from the original three:

(i) The role of the hydrologic cycle in land-atmosphere interactions. Studies of the rate and magnitude of hydrologic processes and their impact on climate at the regional and global scale.

(ii) Trace gas fluxes from ecosystems and their fate in the troposphere. Studies, using remote sensing and in-situ methods, to measure and model the emissions of radiatively and photochemically important trace gases from ecosystems and their chemistry and transport in the troposphere.

(iii) Detection of changes and identification of forcings to the greenhouse effect in the climate system. Reanalysis of data sets of which may provide "signals" of climate change, e.g. temperature, radiation budget and clouds, vegetation index, atmospheric moisture, polar ice, ice sheet volume, global ocean volume, and stratospheric temperatures. Any observed trends in these parameters will then be compared to theoretical predictions.

(6) Future Research Program Related to Global Change--Earth Observing System (Eos):

Eos, the Earth Observing System has been recognized by the Earth System Science Committee as the center piece of NASA's activities with respect to understanding global change. Space offers a unique perspective of the Earth from which consistent measurements of global observations can be made. By capitalizing on increases in spacecraft size and capability, improvements in remote sensing instrumentation, and advances in data and information systems Eos, if approved, will be able to measure many parameters of the Earth system in new ways which are consistent with the time and space scales of the phenomena under study. Eos will also provide a sustained capability which can extend the time horizons of observations now underway or which will be initiated by the missions preceding Eos. The atmosphere, oceans, and land surface will be characterized in a comprehensive manner covering both localized targets and the whole planet with frequent measurements. Eos data will be essential for answering research questions on the global cycles of water and the biogeochemical elements essential for life, the flow of external and internal energy through the Earth system, and specific topics in virtually all of the traditional disciplines of Earth science.

NASA is proceeding with planning for the Eos mission and with development of certain elements within the Eos program. Specifically, Eos will make use of the polar platforms being developed as part of the international Space Station effort. The block 1 portion of the Space Station program which is now underway includes a U.S. polar platform for carrying Eos payloads. The European Space Agency is actively considering provision of a European polar platform as part of their contribution to the initial Space Station complex and NASA is strongly encouraging them to do this. NASA also has funding to develop two facility class instruments which form a significant part of the eventual Eos payload, namely the High Resolution Imaging Spectrometer (HIRIS) and the Space Imaging Radar (SIR). The SIR will initially fly on the Space Shuttle. A number of our on-going flight mission developments are laying the foundation for the Eos instrumentation, since one of the keys to understanding the Earth is long-term continuity in datasets of key Earth variables and this is a vital part of Eos.

The Earth science community has recognized that operational datasets such as those collected from satellites by NOAA represent a significant contribution to long-term, consistent measurements of the Earth. This specific character of operational data acquisition is now shared by many of the research measurements which are to be developed. On this basis, NASA has worked extensively with NOAA to harmonize the planning for future research and operational systems. Our goal is to improve the utility of operational data to the research community and to make research instrument development more readily available to the operational activities of the government. NOAA and NASA are currently planning to share the polar platforms being provided through the Space Station program by flying a combined research and operational payload. The NOAA payload will meet several specific requirements of the research community for Eos including atmospheric sounding, ozone monitoring, data collection and location services, and direct broadcast capabilities. NASA's payload will include several new capabilities designed to meet the research needs in Earth science. The operational community will have this data available and can begin to make use of it in developing new operational products.

The Space Station planning at NASA is being done in concert with Japan, ESA, and Canada as potential international partners. This has helped to stimulate a strong international planning effort to prepare for Eos. Representatives of the Earth observations offices of the Space agencies involved have been meeting for over a year to coordinate the plans for the provision of instruments and science investigations as part of the Eos effort. NOAA and Eumetsat delegates have been included to broaden operational cooperation and coordination as well. This international Coordination Working Group has developed scenarios for how to allocate the required instrumentation among the initial NASA and ESA polar platforms. These plans include substantial instrument contributions by Japan and Europe to the U.S. platform payloads and by NASA and NOAA to the ESA and Japanese platform payloads. Considerable cost sharing appears to be possible. NASA, ESA, and Japan released coordinated Announcements of Opportunity in January 1988 which solicited instruments and other scientific investigations using Eos data from the international Earth science community. The selecting officials of all three partners are committed to coordinating our choices of payloads for eventual development. Broad international participation in the Global Change effort is required if essential exchanges of ground based data from within national borders is to be achieved. This international coordination in space is a key step toward this goal.

Global Data Sets Relevant to Global Climate Change

It is clear from the previous discussion that to document and understand global climate change will require data on a multitude of parameters from cloud cover, radiation balance, precipitation, and atmospheric and oceanic circulation to vegetation type and density, atmospheric trace gases, and ocean primary productivity and chemical and biological fluxes at the boundaries of land, ocean and atmosphere. Current NOAA, ESA, Japanese and Indian operational satellites produce routine data products that need careful validation of a number of parameters including cloud cover, sea surface temperature, atmospheric temperature profiles, vegetation index, and ice cover. The International Satellite Land Surface Climatology Program (ISLSCP) is planning to produce validated data sets on surface albedo, land surface temperature, vegetation cover, and evaporation and transpiration. A number of research satellite missions during the last decade, including the Nimbus series, Seasat, GOES, and shuttle based tests of instruments have demonstated an ability to measure a wide range of parameters including, ocean primary productivity, surface winds, ocean currents, sea ice, radiation budget, solar flux, stratospheric aerosols, ozone, and numerous stratospheric gases. However, there are still other measurements including precipitation, tropospheric composition, and soil moisture which have not yet been adequately demonstrated, thus requiring further technique studies.

In order to obtain the required global data sets will require continued operational space measurements from both polar orbits and geostationary, special research and new operational missions such as ERS-1, UARS, TOPEX/POSEIDEN, MOS-1, the planned Eos , etc., and in-situ validation and calibration together with sophisticated data/information systems. It is clear that if we want to understand the natural variability of the system and differentiate it from human induced changes then special attention must be paid to calibration and continuity of global data sets.

(A) Atmospheric Composition:

The only parameters for which there are true global data sets are ozone and temperature. In each case there are satellite observations and extensive ground-based networks. The satellite observations have only been collected for a relatively short period of time, i.e. less than 15 years, whereas the ground based observations at least extend back to 1958 and in some cases even longer. In the absence of long precise records it is impossible to know the extent of natural variability in atmospheric composition and thermal structure.

Ozone is being monitored using the Solar Backscatter Ultraviolet (SBUV) instrument on the operational meteorological satellites, the Nimbus 7 research satellite, and the international ground-based Dobson network. Based on data from the ground-based Dobson network it appears that the natural variability of global total column ozone is of the order of 3-4% over a decade. However, this assumption is based on only a 30 year record with less than perfect calibration. Current satellite data is also less than satisfactory to observe long-term trends unless great care is taken to differentiate between a drift in the calibration of the satellite sensor from a true change in ozone. Significant effort has recently been expended by the scientific community to re-evaluate the accuracy and precision of both the historical ground-based and satellite data for total column ozone and the vertical distribution of ozone. One excellent example of satellite data verifying a ground-based observation and further exploring the temporal and spatial characteristics of a change in an environmental parameter is where data from the the Nimbus 7 Total Ozone Mapping Spectrometer (TOMS) has been used to examine the Antarctic ozone hole.

The quality of the balloon, rocket, and satellite data for stratospheric temperatures is thought to be even poorer than that for stratospheric ozone. It is also currently being critically re-examined in order to evaluate whether there is any evidence for a cooling of the statosphere as predicted theoretically due to increased levels of carbon dioxide and decreased levels of ozone.

Two instruments flown on the Nimbus 7 satellite, the Limb Infrared Monitor of the Stratosphere (LIMS) and the Stratospheric and Mesospheric Sounder (SAMS), demonstated that a large number of chemical constituents important for understanding the chemical and physical processes controlling atmospheric ozone can be measured with a high degree of accuracy and precision. The LIMS instrument obtained 7 months of data on the global distributions of ozone, nitrogen dioxide, nitric acid, and water vapor, and the SAMS instrument obtained 4 years of data on the global distributions of methane and nitrous oxide.

The Upper Atmospheric Research Satellite (UARS), for which the launch date is uncertain due to Challenger manifest changes but is currently scheduled for 1991, will provide the first simultaneous measurements of the atmospheric distributions of oxygen, hydrogen, nitrogen, and chlorine species, coupled with measurements of temperature, dynamical quantities such as winds, and energy inputs and losses. These measurements will allow us to study the coupling between the chemical, radiative, and dynamical processes which control the chemical composition and structure of the stratosphere, and, in particular, the amount and distribution of ozone, in a manner never before possible, the mechanisms responsible for atmospheric variability, and the response of the stratosphere to changes in external factors such as solar activity and natural phenomena such as volcanic eruptions.

The only tropospheric constituent measured from space is carbon monoxide which plays a critical role in tropospheric chemistry. The data record is only days as it was measured by the Measurement of Air Pollution from Satellite (MAPS) experiment during a space shuttle mission. However, it is important that the feasibility of measuring this key chemical from space has been demonstrated because the gas exibits significant variability in the troposphere.

There are ground-based data sets which adequately represent tropospheric distributions for long-lived trace gases such as carbon dioxide, methane, nitrous oxide, and the chlorofluorocarbons. However, the data records, with the exception of carbon dioxide, are relatively short. While the present network is adequate for monitoring the steady increase of carbon dioxide, which is due primarily to the burning of fossil fuels and secondarily to deforestation, it may not be adequate for studying sources and sinks, where it is necessary to monitor the geographic and seasonal variations. This may require a space-borne monitoring system which is not possible with present-day technology because of the need for very high precision. Space-borne lidar may make it possible to develop such sensors for deployment in the 1990's.

The final design and initial implementation of "A Network for the Detection of Stratospheric Change" is a high priority for detecting and understanding changes in the chemical composition and physical structure of the stratosphere. Successful implementation of this state-of-the-art ground-based remote sensing system will require cooperation and coordination at both the national and international level. Active and passive remote sensing systems utilizing the ultraviolet, visible, infra-red, and microwave portions of the electromagnetic spectrum will be used. Instrument development is cuurently underway for most of the proposed techniques. Discussions on the implementation and operation of this system are currently in progress with NOAA.

(B) Atmospheric Radiation:

The major effort in understanding solar and earth radiation is in developing and conducting a solar monitoring program and an Earth Radiation Budget Experiment (ERBE). The former involves a coordinated solar observing system consisting of space-borne instruments-e.g., Solar Maximum Mission (SMM), solar monitors on the Space Transportation System (STS), and rocket calibration flights. The ERBE involves three earth satellites, i.e., two polar-orbiting operational weather satellites and a dedicated mid-inclination satellite, each equipped with earth viewing visible and infrared radiometers and a solar irradiance reference radiometer. In parallel with these activities a broadly based research program, including STS-based experiments, is aimed at understanding the role of radiative energy transport within the earth-atmosphere system and the influence of the radiatively active components of that system on climate. To meet future requirements, new observing system opportunities will be required such as those afforded on the proposed polar platforms of the space station complex, Eos, to replace current systems, improve accuracy and coverage, and expand the list of observable parameters.

The program of solar and earth radiation research consists of a study of radiation parameters and the constituents of the earth-atmosphere system which interact most strongly with the radiation field. The radiation parameters constitute three components of the program: solar radiation, Earth radiation budget at the top of the atmosphere, and surface radiation budget and the relatively active constituents of the climate system comprise the remaining three components: clouds, aerosols, and trace gases.

There is no straightforward way to measure surface radiation components on a global scale: surface networks are too sparse and unevenly distributed and satellite measurements are only indirectly related to surface flux. The strategy, therefore, involves a combination of observations and calculations using theoretical and empirical models. The framework will be a theoretical model based upon the principles of radiative transfer, utilizing satellite observations of a wide range of atmospheric and surface parameters as input. Because of imperfections in the model and insufficient specifications of input parameters, it will be necessary to utilize empirical adjustments. Empirical coefficients will be determined from the analysis of direct observations at selected points on the surface. As the methodology improves, it may be possible to use a smaller set of input parameters and eventually relate the surface radiation fluxes directly to satellite observations in suitably chosen spectral bands. In any event, an important aspect of this activity is the improvement of radiative transfer models. For the long term, an augmentation of existing instruments or a dedicated instrument for satellite monitoring may be necessary.

It is appropriate to identify the land surface as a separate program component because of the effect of changes in snow, ice, and vegetation cover, soil moisture, and land use on the albedo and emissivity of the surface. Consequently, although these parameters are closely tied to the surface radiation budget they are discussed later.

(i) Solar Radiation:

Available evidence suggests that there might be significant changes in total solar irradiance occurring on a time scale of months to years. Establishing the nature of these variations and their significance to climate is the objective of an ongoing solar irradiance monitoring program comprised of experiments on rockets, satellites and the STS. Rocket and Nimbus-ERB measurements began in 1976. The SMM/ACRIM experiment, launched in 1980, provided the baseline measurements near the peak of the most recent solar cycle. The first STS observation was with an ACRIM II in late 1983 in conjunction with Spacelab 1. The program is designed to provide continuing measurements for the solar radiation component with the required sampling frequency, accuracy and long-term precision over at least one solar magnetic cycle. For long-term continuous monitoring, utilization of operational meteorological satellites or research satellites of opportunity will be explored. This program also calls for monitoring spectral variations and for monitoring the solar diameter and establishing its relationship to solar irradiance.

(ii) Earth Radiation at the Top of the Atmosphere:

The major effort in this area involves the ERBE experiment. Careful attention is being given to calibration and to the development of improved techniques for converting measurements at satellite altitude to earth radiation budget components at the top of the atmosphere. Data from the Nimbus 6 and 7 satellites will continue to be processed to develop a long-term data set. Alternative schemes for post-ERBE measurements will be evaluated, including the reliance on NOAA earth radiation budget products derived from the operational imaging radiometer.

(iii) Clouds:

Clouds can result in either cooling or heating the Earth depending upon their type and altitude. There is an international effort to develop a 5-year global cloud climatology based upon operational imaging radiometer data from as many as 5 geostationary satellites and 2 polar orbiters. The International Satellite Cloud Climatology Project (ISCCP) is jointly sponsored by the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU) as part of the World Climate Research Programme. The ISCCP will collect and analyze satellite radiance data to infer the global distribution of cloud radiative properties in order to improve the modeling of cloud effects on climate.

The development of the data set will be backed up by research to improve the techniques for remote sensing of cloud parameters, climate sensitivity studies to determine the relative importance and observation requirements for various cloud parameters, and investigations to diagnose and improve the methods for parameterizing clouds in climate models. Because of the need for data at the high resolution associated with cloud formation and dissipation processes, there will be a series of multiplatform regional experiments - utilizing operational satellites, aircraft, balloons, and surface observations - under the aegis of the National Climate Program, designated the First ISCCP Regional Experiment (FIRE).

The central objectives of FIRE are to quantify the capabilities of current models for large scale cloud systems and for their effects on radiation, and to obtain data and understanding necessary to improve these models. A secondary objective is to check and, where possible, improve the interpretation of global statistics on cloud parameters which will be collected by International Satellite Cloud Climatology Project (ISCCP).

Physical process modeling, which includes all processes important to the characterization and evolution of cloud systems, and large scale GCM and climate modeling are critical to FIRE's success; these extremely important modeling components will be integrated into FIRE through the participation of modeling researchers in the FIRE Task Groups. In this way modelers will participate in all phases of FIRE. In the late 1980's the opportunity will arise to use the STS in support of these types of experiments.

(d) Aerosols:

Because the evidence is fairly strong that stratospheric aerosols, such as those induced by major volcanic eruptions do affect the stratospheric temperatures and the earth's energy budget, it is important to develop an aerosol climatology and a long-term monitoring plan. The data from Nimbus 7 satellite SAM II instrument and AEM-2 satellite Stratospheric Aerosol and Gas Experiment (SAGE) experiment, along with correlative measurements from surface, aircraft, and balloon platforms, will be used to establish a data base. Measurements of stratospheric aerosol optical depth between May 1980 and December 1980 following the eruptions of Mount St. Helens in May 1980 clearly shows the manner in which the aerosols were transported globally. Knowledge gained from the evaluation and analysis of these data will be used to establish observing requirements and plan for a long-term monitoring system. While tropospheric aerosols could also be important to climate, their impact is not as well established. Because of their heterogeneous nature and short residence times, and the ubiquitous presence of clouds they are not easily susceptible to satellite monitoring. The availability of space-borne lidar systems beginning in the early 1990's would provide an opportunity to test and evaluate a tropospheric aerosol sensor

(C) Land Surface Properties:

It is well known that climate fluctuations and trends may have effects on society on a regional as well as on a global scale. Land observations from satellites will also become part of a data base for monitoring changes of the surface, for instance of vegetation and snow cover, and of the climate of the surface of the earth. Such monitoring is particularly urgent at the present time due to the possibility that man's activities may have climatic consequences.

Changes in agricultural practices may lead to regional desertification or deforestation, which can lead to regional changes in the energy and moisture budgets. Draining wetlands can cause large changes in methane production, another important gas related to global temperature changes. It is clear that global, continuous monitoring of such anthropogenically induced changes, as well as naturally occurring variations, can only be obtained from satellites.

A vital component of the International Satellite Land Surface Climatology Project is to develop methodologies for deriving quantitative information concerning land surface climatological variables from satellite observations of radiation reflected and emitted by the earth. Such quantitative information is required to:

(1) Monitor global scale change of the land surface caused by climatic variations or by human activity;

(2) Further develop mathematical models designed to predict or simulate climate at various time scales;

(3) Permit inclusion of land surface climatological variables in diagnostic and empirical studies of climate variations.

The time is appropriate for conducting such studies because of the increasing sophistication both of remotely sensed observations from space and the development of improved climate and medium range weather prediction models.

The land surface variables of interest and potentially obtainable more or less directly from satellite observations are vegetation cover, albedo, solar radiation, longwave radiation, skin temperatures, emissivity, soil moisture, and snow cover and depth. The work may be divided into two parts in present research.

(1) Evaluation of existing satellite data collected in the last fifteen years to determine their usefulness in detecting climate related fluctuations or man-induced changes in the surface of the Earth.

(2) Development and validation of methods to convert satellite-observed radiances to surface climatological variables. The validation effort will require intercomparison of satellite-derived quantities with simultaneous ground- and aircraft-based measurements, to be carried out in field programs in selected areas.

(i) AVHRR NDVI Global Data Sets:

Composite data sets using the Normalized Difference Vegetation Index (NDVI), based on ratioing the reflectance in red and near infrared wavelengths, are being generated for mid-1981 to present for all of the earth's land surface. These data will provide a long- term record of the changes in surface vegetation cover, and have already been used successfully on continental data sets for:

- * Monitoring and estimating terrestrial primary production
- * Monitoring changes in land cover (e.g., deforestation, desertification)
- * Land cover classification
- * Monitoring and predicting ecologically-linked insect and disease outbreaks

(NOTE: 1 km resolution historical data sets are available for selected regions of the world, e.g., the Sahel)

(ii) SMMR Global Data Sets:

Monthly data sets, at 25 - 150 kilometer resolution, of brightness temperature for the period from 1979 to the present for the earth's land surface are being produced using data from the Scanning Multichannel Microwave Radiometer (SMMR) on Nimbus 7. The channels at 6.6 and 37 GHz from this passive microwave instrument have been used to produce information about surface moisture conditions. Research is actively underway to better understand the utility of these data. These data sets provide information complementary to that of the AVHRR. The SMMR data is a measure of the water content of the vegetation, and is also a measure of surface roughness. The following terrestrial applications are being researched:

- * use of 6.6 GHz horizontally polarized brightness temperature to estimate surface wetness (soil moisture)
- * use of 37 Ghz polarization difference data to obtain information about vegetation water content (this technique seems to be most sensitive in semi-arid regions)

(iii) LANDSAT MSS Data Sets for Climatically Sensitive Areas of the Globe:

Landsat 1-3 MSS (MultiSpectral Scanner) data for selected regions of the world, collected during the period 1972 -1978, have been preserved by NASA through processing from old wideband analog tapes to CCT formatted digital tapes and archiving. Over 40,000 scenes have been preserved. One subset of over two thousand scenes was chosen to represent those areas deemed particularly sensitive to climatic change: semi-arid regions, desert margins, cold-margins with seasonal snow cover, and areas of extensive deforestation. Research is now underway within the International Satellite Land Surface Climatology Project (ISLSCP) to analyze land cover and albedo changes in certain semi-arid regions of the world using some of these historical data sets.

(iv) Synthetic Aperture Radar (SAR) Data Sets:

Synthetic aperture radar (SAR) data sets from Seasat and the Shuttle Imaging Radar (SIR) series for selected portions of the earth's surface have been archived and are currently being studied. The SAR on Seasat was launched in 1978 and collected L-band (23 cm wavelength) data at a 23 degree incidence angle over North America, the North Atlantic and Europe. These data were

- * Discriminating major lithologic units by their surface texture differences
- * Observing variations in soil moisture

In 1981, the Shuttle Imaging Radar - A (SIR-A) imaged selected portions of the globe between 41 degrees north and 35 degrees south latitude. SIR-A also operated at L-band, but collected data at a 45 degree incidence angle. These data have been used for geomorphologic studies of remote areas, and demonstrated the following additional capabilities of L-band:

* Imaging of subsurface features in very arid environments
* Observation of standing water beneath forest canopies
* Observation of deforestation in tropical environments
* Observation of the geomorphology of remote areas of the world, never before mapped due to cloud cover

A follow on instrument, SIR-B, was launched in 1984 adding multiple incidence angle and digital image processing capabilities (for improved radiometric quality) to the SAR. Digital data were collected globally between 60 degrees north and south latitude. Experiments similar to those of SIR-A were conducted. Additionally, the following new experiments were conducted:

* Creation of digital topographic maps directly from radar imagery
* Generation of image classifications based on scattering properties of the surface

SIR-C, the next generation imaging radar, is being built for launch in 1991 and 1993. It will collect data at C-band (6 cm) as well as L-band, and will fly with a German built X-band (3 cm) SAR. SIR-C will also have the capability to collect multiply polarized data, which in concert with its multiple frequency capabilities will provide a powerful tool for numerous new experiments:

* to understand vegetation canopy structure
* to understand arid region surface penetration
* to provide measurements of surface scattering properties at various scales.
* to provide calibrated multitemporal observations of vegetation.

Areal coverage will be worldwide within the same latitude range as SIR-B.

In addition, NASA is establishing the Alaska SAR facility (ASF) at the University of Alaska in Fairbanks to receive, process, analyze, archive, and distribute SAR data received from both the European and the Japanese ERS-1 missions. As such the ASF offers the US research community acess to SAR data from these missions, as well an opportunity to collaborate with scientists from those countries.

(D) Ocean Properties:

(i) Ocean Productivity:

Biological productivity can be determined through measurements of ocean color, which depends primarily on the photosynthetic pigments (chlorophyll) contained in marine plants. Since these plants are the basis of the marine food web, measurements of their amount and distribution are critical to obtaining a better understanding of biological and chemical processes, including the cycling of carbon through the oceanic ecosystems. All of these measurements should be well distributed over the globe and made regularly to determine natural variability. Such coverage can be provided only from a space-based program operating over a period of several years. The Coastal Zone Color Scanner (CZCS) which was launched in 1978 and operated until 1986 on the Nimbus 7 satellite has demonstated that phytoplankton chlorophyll pigment concentrations can be measured. Satellite data show that there is a strong correlation between sea surface temperature and ocean color due to coastal upwelling, and it is also evident that to determine primary productivity in coastal areas requires a space perspective because of the small scale variability which would be impossible to monitor with conventional ship-board measurements. Future measurements of ocean color could be made using the proposed Ocean Color Imager (OCI), or the proposed MODIS Eos instrument described earlier.

(ii) Ocean Circulation:

Sea surface winds, a fundamental driving force for ocean waves and currents, also profoundly influence the exchange of heat between the atmosphere and the ocean. On a global scale the winds and the ocean currents are thought to be equal partners in redistributing the excess solar heat gained in the tropics to the cooler polar regions. Thus our knowledge of their dynamics is crucial to our understanding of our climate. In 1978 the radar scatterometer on Seasat was used to derive the first global measurements of winds over the oceans. During the 1990's NASA plans to fly the next generation scatterometer (NSCAT). During this mission global synoptic wind data will be collected to study surface waves, wind-driven ocean circulation, and air-sea interaction.

As stated above ocean currents play a major role in the redistribution of thermal energy between the equator and the polar regions. The altimeter on Seasat demonstated the ability to accurately measure sea-surface topography, and hence derive ocean currents and eddies. Given that sea surface topography is influenced not only by ocean currents but also by the Earth's uneven gravity fields, due to the uneven arrangement of the Earth's mass, it is desirable to have an accurate knowledge of the Earth's gravity field in order to seperate out the influence of gravity, which should be constant in time, and ocean circulation on the sea surface topography. NASA plans to launch the Ocean Topography Experiment (TOPEX) along with the French POSEIDON oceanographic mission in 1991. TOPEX should provide three years of accurate sea level data in order to study ocean currents, eddies and other features of ocean circulation.

Monitoring global temperatures, especially from the oceans, has traditionally been impossible because of the lack of data from many areas. However, satellite data has now overcome this difficulty.

(iii) Polar Ice Cover:

Ice and snow cover a significant portion of the Earth's surface and thus strongly influence global climate. Antarctic sea ice in winter covers an area greater than the United States and acts as an insulating barrier that regulates the rate at which heat can be exchanged between the atmosphere and the oceans. Monitoring seasonal and year to year variations in sea ice cover is critical to developing our understanding of climate, and changes in this quantity may be an indicator of global climate change. Microwave sensors can measure the extent of sea ice cover and such sensors have been in orbit since 1973. Such data has been used to show that the extent and distribution of sea ice has varied quite significantly since 1973, decreasing from 1973 to 1978 and increasing thereafter.

In order to exploit the potential offered by this next generation of oceanographic sensors, NASA is working with the NSF, U.S. Navy, and NOAA, as well as with our international partners to plan a set of comprehensive at-sea experiments. Two examples are the Tropical Ocean Global Atmosphere and World Ocean Circulation Experiments being organized under the World Climate Research Program (WCRP).

(E) Examples of Future Global Data Sets (Planned For Eos)

MODIS - The planned Moderate Resolution Imaging Spectrometer (MODIS) is a system of two imaging spectroradiometer components designed for wide applicability to research tasks that require long-term (5 to 10 years), low resolution (0.5 to 1.0 kilometer), global, multispectral (52 channels between 0.4 and 12.0 micrometers) data sets. Anticipated terrestrial applications of MODIS data include studies of:

- extent and rate of tropical deforestation and regrowth
- extent and rate of desertification at the edges of the world's deserts
- areal distribution and effect of acid rain on the forests of Europe and North America
- updates on global vegetation maps
- extent of drought or freeze damage in croplands and natural communities
- land cover change and its effect on terrestrial biophysical systems
- continental changes in snow cover and associated changes in albedo
- derived products such as standing green biomass, intercepted photosynthetically active radiation, and net primary productivity

Data from MODIS will be used to drive simulation models of global surface climate, the carbon cycle, the hydrologic and energy cycles, and comprehensive biogeochemical cycles.

HIRIS - The planned High Resolution Imaging Spectrometer (HIRIS) is a flexible, high spectral resolution (192 continuous 10 nanometer channels from 0.4 to 2.5 micrometers), high spatial resolution (30 meters) imaging spectrometer designed to provide detailed coverage of the earth's surface on a local basis. Anticipated terrestrial applications of HIRIS data include studies of:

- identification of the composition of surface materials (mineral identification for geological applications and potentially identification of the biochemical constituents of vegetation)
- fine scale features (surface geology land cover types of inherent small scale agricultural crop assessments)
- fine scale processes (phenomenon in inland aquatic systems, slash and burn deforestation, changes in vegetation composition and biogeochemistry)
- detailed grain structure of snow cover

Nested use of HIRIS with MODIS data will be necessary to yield global interpretations of many terrestrial phenomenon.

Eos SAR - The planned Eos Synthetic Aperture Radar (SAR) is a flexible multifrequency (L-, C- and X-band), multipolarization, high spatial resolution (30 meters), imaging radar capable of observing the earth using a variety of viewing geometries. Anticipated terrestrial applications of Eos SAR data include studies of:

- Ice and snowpack extent, condition, and change
- Surface roughness (erosion, landform patterns, geomorphology)
- Soil moisture
- Vegetation canopy structure (geometry, biomass)
- Vegetation canopy water content
- Geological structure and tectonics
- Lithologic boundaries

HMMR - The planned High-Resolution Multifrequency Microwave Radiometer (HMMR) is a complement of passive microwave instruments. Those for the earth's land surface were designed to yield long-term, low resolution (10 kilometers at the lowest frequencies), global, multifrequency (1.4, 6, 10, 18, 21, 37, and 91 GHz) imagery. Anticipated terrestrial applications of HMMR data include studies of:

- soil moisture
- precipitation
- snow cover and moisture equivalent
- derived evapotranspiration

Summary:

In summary, it is clear that significant progress has been made in our understanding of the physical and chemical processes that control the distribution of ozone and the temperature structure of the atmosphere. However, we must recognize that significant uncertainties in our knowledge remain, and that these can only be resolved by a continued program of research. Given what we know about issues such as ozone and greenhouse warming we should recognize that we are conducting a global scale experiment on the Earth's atmosphere without a full understanding of the consequences. The Antarctic ozone phenomenon which was completely unexpected vividly demonstrates that the environment does not always change slowly, linearly, or predictably in response to a perturbation.

Understanding these and related issues should clearly be a priority for the scientific and policy communities. This will require a comprehensive coordinated national and international research effort. Wise policy decisions require an improved understanding of the way in which the Earth's environment varies naturally and in response to human activities.

Satellite data, if well calibrated and continuous, can provide the data sets required to document and understand global climate change. At present the ability to measure many of the needed ocean, land, and atmospheric parameters has been demonstrated. However, there are presently very few global data sets, satellite or ground-based, of the quality and length neccesary to contribute to documenting global change. If we wish to have available, in the future, a documented data-base of global change, we must begin now to establish those systems that will obtain the required comprehensive data. NASA is firmly committed to working closely with all other Federal agencies and international organizations. Of course, NASA recognizes the fiscal realities that confront us and will continue to evaluate our efforts within the context of the rest of our space program and other federal and non-federal activities.

Table 1

Updated Global Trends and Tropospheric Concentrations of Source Gases for 1986

(Where appropriate and available, lifetimes are also tabulated.)

Source Gas	Concentration 1986 pptv	Rate of increase 1986 pptv/yr	%/yr	Lifetime[a] yr
CCl_2F_2(a)	392	16.7	4.3	111^{+222}_{-44}
CCl_3F(a)	226	9.0	4.0	74^{+31}_{-17}
CH_3CCl_3(a)	139	6.2	4.5	7±1
CCl_4(a,b)	129	1.8	1.4	≈40
CCl_2FCClF_2(b)	32	3.6	11.3	≈90
$CHClF_2$(b)	92	6.5(c)	7.1	≈20
CH_3Cl	≈600	-	-	≈ 1.5
$CBrF_3$(b)	2.0	0.3	15	≈110
$CBrClF_2$(b)	1.7	0.2	12	≈25
CH_3Br(b)	10-15	?		≈2
N_2O	$(306\text{-}309)\times10^3$	$(0.65\text{-}0.8)\times10^3$	0.2-0.3	≈150
CH_4(d)	1638×10^3	$(13\text{-}16)\times10^3$	0.8-1.0	≈10
CO(b)	103×10^3	(see 8.7)		0.1-0.2
CO_2(d)	345×10^6	1.2×10^6	0.4	
Total Cl(e)	3185	104	3.3	
Total F(e)	1300	67.5	5.2	
Total Br(e)	14-19	0.5	3-4	

(a) The lifetimes of the first four species has been derived from observations (see Chapter 8.2), the others are adopted from WMO (1986).

(b) Calibration uncertain.

(c) Southern Hemisphere.

(d) 1985 data.

(e) The total amounts include all the appropriate compounds listed in this Table, which are thought to be the major species of global importance. Because of its exceedingly long lifetime CF_4 is not included in total F.

Senator **Wirth**. Thank you, Dr. Watson.

Senator **Bradley**. I would like to ask a question if I could, Mr. Chairman.

In Dr. Schneider's testimony, you have a sentence or two where you say, "Quite simply, the faster the climate is forced to change, the more likely there will be unexpected surprises lurking."

Dr. **Schneider**. Yes.

Senator **Bradley**. And then you have a list of questions that you recommend we ask the experts. I presume that you can tell me what some of those surprises are that might be lurking. And then I would like to ask the experts your questions and include you in the list, and hope that Mr. Albritton will address the questions that you pose in your testimony which are what can happen when we talk about global warming. What can happen? What are the probabilities of alternative outcomes that you foresee? And how did you determine these odds? And what are the potential consequences should the outcomes occur? Dr. Schneider and Dr. Albritton?

Dr. **Schneider**. Before I address the list, you had asked something earlier.

Senator **Bradley**. Pardon?

Dr. **Schneider**. You had asked at the beginning of your——

Senator **Bradley**. What are the surprises lurking?

Dr. **Schneider**. Oh, surprises, OK.

A surprise I suppose is by definition something that you don't know what is going to happen. And I really wasn't trying to set up somebody to ask me that question, although I greatly appreciate it, because the reasons that Dr. Watson just said is that we know that there have been rapid changes in the past that have occurred in the climate in ancient times that are not understood. And if they are not understood, we don't know whether we are near a plateau where a slight——

Senator **Bradley**. What surprises lurked then since we know that that occurred?

Dr. **Schneider**. Well, for example, about 10,800 years ago, the world was about finished with the ice age, and then in a matter of less than 100 years, it was plunged back into almost ice age conditions, a time the geologists called the younger dryas, a dryas being a flower that likes the mountains. It lives in the tundra. And that had expanded out back down into mid-latitudes. And this period lasted something on the order of 800 years, and then eventually our present warm interglacial took place.

Well, that is an issue that is now getting considerable attention because it occurred relatively rapidly and most of our climatic theories would suggest that the climate would change more slowly than that kind of change.

There may be surprises of a different nature rather than just quick glaciations. There might be a—a surprise would be—this is speculation, of course. The Arctic Ocean is covered with sea ice now. And if one warms the climate to a certain point, it is possible that that non-linear processes that Dr. Watson mentioned could have that ice all of a sudden disappear if one passes a certain threshold of warmth which would then have implications for atmospheric circulation patterns that we haven't begun to explore.

The key is the faster we change the climate——

Senator **Bradley**. Could you quantify that at all? In other words, how much would the temperature have to go up before the glacial ice would be melted?

Dr. **Schneider**. I certainly can't quantify it now. One of the experiments that we are performing at home with our computer models—and these models are very, very dirty crystal balls. They are not completely opaque, but then they have got lots of dirt on the glass.

Senator **Bradley**. Can you quantify it, Dr. Albritton?

Dr. **Albritton**. No.

Senator **Bradley**. So, no one. Science can't quantify it for us.

Dr. **Schneider**. We are trying to look at how much energy it would take. It is not the same thing as how much temperature it would take.

Senator **Bradley**. Well, can you quantify it not specifically but in orders of magnitude? We have heard that the temperature of the world is 1 degree higher this year. How much more would it have to be over time?

Dr. **Schneider**. Well, the U.S. Geological Survey——

Senator **Bradley**. Range, 5 degrees, 10 degrees?

Dr. **Schneider**. Five probably. The U.S. Geological Survey is starting to look at a period in earth history when we believe there was no ice in the Arctic Ocean area, at least certainly not in the summer. And that is called the Pliocene, something like 3 million to 4 million years ago. And what they are trying to do is find out exactly how warm it was then, what was the sea level then, and is this a good metaphor. In a sense, has the earth performed this experiment for us?

Senator **Bradley**. But what can you tell us today?

Dr. **Schneider**. Five degrees.

Senator **Bradley**. I only say this because if you try to explain this issue in terms of references to 10,000 years ago and debates within the scientific community, the urgency that all of you feel and that many of us feel is diminished. So, in posing your questions to you, this is your opportunity to make this issue more accessible to greater numbers of people.

So, what can happen? What are the probabilities of alternative outcomes? And how did you determine the odds? And what are the potential consequences? Dr. Albritton, do you want to take a crack at that?

Dr. **Albritton**. Let me subdivide the question into two parts. One, I will deal with surprises. This is how you introduced the question. And then I will comment very briefly on—just underscore some of the remarks made earlier about what current science is predicting could happen if the greenhouse gases continue to increase.

In terms of surprises, let me focus not on the ice ages, but on the last 100 years and even the last few years to give examples of how imperfect knowledge sits on the table in front of us as a challenge or how the failure to understand this system sufficiently caused us to miss a big call in terms of sciences.

The temperature record which we have for about 150 years now has two unusual features in it in recent decades. Rather than a steady increase in temperature as would be predicted to occur, if that change were driven by greenhouse gas increases, the half a degree that we have seen in the last 50 to 100 years increase, half a degree Celsius, has occurred in two jumps. And since we feel that the greenhouse response to increasing trace gases in the atmosphere would be a smooth increase, it is telling us that there are aspects of this climate system we don't have fully embraced yet. That is, there are other processes at work that cause temperatures to change often abruptly. And since we cannot yet explain why those changes occurred in the 1920s, we have a difficult time dealing with the——

Senator **Bradley**. In the 1920s?

Dr. **Albritton**. Yes. In the 1920s a good fraction of that increase occurred. A good fraction of the remainder of that increase occurred in our present decade.

And so, frequently when the question is asked are the warm 1980s a result of the greenhouse effect, we have to indicate that while the overall temperature change is consistent with the greenhouse prediction, those two lurches—call them surprises, as you did earlier—give us some uneasiness in attributing a particular warm decade to a particular cause and effect.

Probably, though, the rudest surprise that the atmospheric scientist has had is the one that my colleague, Bob Watson, alluded to. And that is, we have studied the ozone-chlorine issue for a decade and a half, and have made great progress in understanding the global effects of chlorine on ozone.

But just in the middle of looking for whether a half a percent or a percent change has, indeed, occurred, something totally unusual happened in Antarctica. Half of the ozone disappeared in a very unusual way, namely, only in Antarctica and only in the Antarctic spring, and then it fills back in. This was only 2 years ago after we had studied the problem for a decade and a half.

I think, though—and I will rush to the defense of the community—in the 2 years since the Antarctic ozone hole has been discovered, there was an enormous amount of activity. And because ozone had been studied for a decade, in fact, now we have a fairly clear picture as to what happened on that surprise. So, I think the point here is twofold.

Senator **Bradley**. Well, what did happen? You have me on the edge of my seat. [Laughter.]

Dr. **Albritton**. Our present picture is the following. It is not due to natural processes involving climate change. It is not due to sunspot activity as was postulated. It appears to be due to the following. In Antarctica, which is the coldest spot on the planet, the stratosphere is so cold that ice can form spontaneously. The presence of that ice alters the chemistry in the Antarctic stratosphere. It alters it in a way that accelerates the chlorine-ozone chemistry faster there than anywhere else on the planet. And our present picture then is that while the natural scene of Antarctica sets the stage, it is our manmade chlorine compounds that are depleting the ozone over Antarctica.

Senator **Bradley**. So, the ozone is depleted over Antarctica in the spring for a certain period of time. Then it fills in. So, what is the effect of the ozone layer being depleted in Antarctica? Is it not elaboratory as to what might happen elsewhere if the ozone layer were——

Dr. **Albritton**. That is a very interesting question. It is more difficult to answer than what is the cause of what is happening in Antarctica. Let me pose your question in two parts.

What is the consequence of the loss of Antarctic ozone to the rest of the world? For example, could such a thing occur over the north pole? I think we do know that a hole of that magnitude probably is unlikely over the Arctic part of the globe.

However, the question that is still open—and NASA and NOAA and other agencies are planning to address it in an airborne campaign early next year—is could a small fraction of that hole be occurring over the Arctic. After all, it does get rather cold there although not as cold as Antarctica. And, therefore, one has to worry about smaller effects occurring.

The influence of taking a notch out of the ozone over the south pole on the rest of the planet is an open research question. It may have influences on the southern hemisphere; it may not. It is an open question. And so, while I think the community could feel good that it has over a short period discovered the cause of this surprise, it still has a lot of work to do in terms of understanding its global implications.

But I think perhaps for this hearing the question that is most interesting is what have we learned about the surprise that occurred in Antarctica. And I think what we have learned is that perhaps Mother Nature was kind, and that is for the very first large scale alteration of our planet by our own activities, it allowed that to happen over Antarctica. And I think this underscores the need for the fundamental understanding of the system. We have no guarantee that the next surprise of that magnitude will not be in such a region that would have a minimum impact on human activities.

Senator **Wirth**. At the height of the ice age, how much colder on average was it than it is on average in 1980?

Dr. **Albritton**. Only a degree or so.

Senator **Wirth**. Wait a minute. Overall. When was the height of the ice age? What was the date of the height of the ice age?

Dr. **Albritton**. A few degrees.

Senator **Wirth**. A few degrees is how many?

Dr. **Albritton**. Three to five.

Senator **Wirth**. At the height of that ice age when there was at some point two miles thick of ice, right, in the North American continent, it was 3 to 5 degrees colder than on average today. Is that right?

Dr. **Schneider**. On a worldwide basis, yes. Obviously, near the edge of the ice much colder than that, 10 or 20 degrees Celsius colder.

Senator **Wirth**. On a worldwide basis at the height of the ice age, it was 3 to 5 degrees colder than it is today. So, one can then extrapolate—you were saying you have to talk in metaphors or extrapolation because we can only experiment with the globe once. You extrapolate to say if we had that kind of an impact from 3 to 5 degrees colder, one might say what are the impacts from it being 3 to 5 degrees warmer. And if 3 to 5 degrees warmer would have probably a very, very significant impact, where are we on that 3 to 5 degrees warmer?

And as I remember the testimony that we had last fall, the expertise there suggested that we have probably already built in about 1 and a half degrees warmer. So, in other words, on a continuum of pretty dramatic change, we have already gone 1 and a half degrees, and 3 to 5 degrees warmer would be very significant up as 3 to 5 degrees colder was very significant down. And that is another way of looking at how much is a degree, how much is 2 degrees, how much is 3 degrees. The ice age tells us a lot about how much 3 to 5 degrees is. Is that an accurate way of looking at the size and scope of 1 degree, 2 degrees, 3 degrees?

Dr. **Schneider**. I think the numbers that you cite are correct, and I look at it that way. But I look at another aspect of it which is the time frame. The 3 to 5 degree warming, if we could take 1,000 years, would bother me less than a 2 degree warming if it takes 50 years because the time rate at which the system can adapt and the damages that would be done to nature from very rapid change are what I fear most. And that 3 to 5 degree number that you cited, which is sort of down the middle of what most models suggest for the mid to the end of the next century, would happen in the time frame of a century. And that is, at least in my personal view, is the basis of my concern, that rapidity.

And when you have changes that fast, it would be arrogant for us to stand here and say that we could tell you what the details were or the surprises. What we are trying to say is that we know something about magnitudes and rates, but the detailed distribution of events is just about impossible to predict if they are going to occur that fast. And, therefore, we have to say that surprises simply have to be expected.

Senator **Bradley**. Could you help me understand why 1, 2, 3 degrees can have such a startling impact on our environment? The common sense notion would be if the temperature every day I get up over a year is 1 degree warmer, what difference does that make.

Dr. **Schneider**. Let's start with the simplest thing that everybody can relate to. Supposing you take the temperature in Washington, D.C. as it has been over the last 100 years and you simply, as we mentioned earlier, assume the climate is like dice. And you roll them and there are various odds of events. One of the events that we worry about is a heat wave, the kind we are in right now. What is the probability in Washington, D.C. of having 5 days in a row or more in July with the afternoon temperature greater than 95 degrees? Well, at present those numbers—and I'm looking to make sure I am right—are about 1 in 6 from the data that I have seen.

If you raise the temperature by 3 degrees Fahrenheit, which Senator Wirth suggested the earlier testimony said we have already committed to, at least over the next 30 to 40 years—we are maybe halfway there. If that is the case, and we increase the temperature by 3 degrees, those odds go from 1 in 6 to something like 1 in 2. Now, what that means for air stagnation, for the health of especially elderly or other vulnerable citizens, is one of the things that EPA has been looking into in their studies. And what that might mean for the loads for air conditioning which would affect the need to either build new power plants or have stronger energy efficiencies are also important. So, that we can relate to quite easily.

I have done the same sort of calculation for Dallas, but we used 100 degrees. What is the odds today of having five days in a row above 100 degrees in Dallas? And it is about 1 in 3. If you increase by 3 degrees Fahrenheit, which is not nearly as far as the 3 to 5 degrees Celsius that Senator Wirth was talking about, then the odds go from 1 in 3 to 2 in 3.

So, you can see that the probability of extreme heat waves would almost certainly go up if nothing else but the temperature mean changed. Those assume that there is no change in the daily variability, which is, as of now, the best assumption we can make. That is easy to relate to.

What else does it mean? Well, it also means that perhaps on the good side that the growing seasons would increase because you would get less commensurate runs of cold days. And presumably that means growing seasons would increase.

You can also calculate what happens to the evaporation from soils and from watersheds if the temperature increases. And, indeed, a number of people are doing that—hydrologists using these kinds of numbers. And the typical kind of thing that you see is that the Colorado River basin might have 10 to 40 percent less runoff under this kind of scenario.

Other people have calculated what it might do to sea level. If you warm the oceans, you are simply going to do what you do with any fluid in a thermometer. If you heat the fluid in a thermometer, it will rise up the tube simply because it expands when it gets hotter. Well, in this case the fluid is the oceans and the tubes are the continental margins. So, if you heat the oceans, they are going to rise, and that is without melting any ice anywhere, just simply heating the oceans. And most suggestions are that sea level could rise—and you wanted probabilities—oh, maybe there is a 10 percent chance that they won't rise and 10 percent they will rise 5 feet in the next 100 years, and sort of everything else in between works out based on these calculations. So, a few degrees can be significant in that way.

And the other most important point is it isn't just the absolute value of temperature that counts. Most of our theories—and these are based on good, I think, sound physical arguments and on experience—suggest that the world is not going to warm up uniformly by, say, 2 degrees in 25 years, but that the middle of continents will warm up faster than will the middle of certain kinds of parts of the ocean. Other parts of the ocean may warm up faster than that if they melt ice.

And that the warming during the transient phase, the transition phase, will be very nonuniform from place to place. The reason that is so important is the temperature differences between land and sea and latitude and latitude are what gives rise to the circulation systems that give us our accustomed climate. That is part of the reason why my colleagues have argued that we can't be very sure of the regional details that we will hear because in order to do that, we have to be able to solve the connection between the atmosphere and the ocean to a high degree of precision. And the storm track is governed by where the Jet Stream is, for example, and the flows of moisture from land breezes and sea breezes, a monsoon, are governed by land-ocean temperature contrasts. And these will change, and these will change in hard to predict ways, particularly the faster we change things.

So, a few degrees temperature really can be very significant not just for the globe, but if that temperature change is distributed nonuniformly as we anticipate, then we can get all kinds of changes in regional climates that could affect crops and water supplies and health and so forth.

Senator **BRADLEY**. Do you all agree that it has been 1 percent increase in the last decade?

Dr. **WATSON**. If you look at the temperature record, it clearly seems to indicate over the last 100 or 120 years somewhere between half a degree and 1 degree Centigrade. So, that would be 1 to 2 degrees Fahrenheit. So, if you look at both the sea surface temperature record and the land surface record, they both suggest half to 1 degree Centigrade.

Senator **BRADLEY**. What changes have we seen in the ocean with this increase?

Dr. **WATSON**. I would have to argue at the moment we have not established any effects due to a potential change of 1 degree C in the earth's atmosphere at the moment. One could argue that we haven't monitored very many things either. So, any strong research program has to have a component that tries to understand processes and to monitor change.

In fact, the only long-term record that we have that is very good to indicate climate is temperature. And there are many other factors that we need to monitor to see if there are good indicators or fingerprints of a climate change, such as albedo over the earth, moisture in the atmosphere, precipitation patterns.

And so, at the moment I would have to say that I don't know of any strong evidence that would suggest that we have seen observed changes in the environment due to the small change in temperature that we seem to have seen.

Senator **BRADLEY**. Would you agree with that, Dr. Albritton?

Dr. **ALBRITTON**. Yes.

Dr. **SCHNEIDER**. One postscript. I apologize for hogging the microphone.

We need to put in some perspective what Bob Watson has said. The magnitude of natural change, the rolling of the climatic dice, if you will, is about that which we have observed over the last 100 years. You can get years where the temperature changes globally by half a degree and bounces around. So, what we are really looking at is what the signal engineers like to call a signal to noise ratio problem where the signal from human-induced climate change is on the verge of emerging from the background noise. So, one would not expect to find a clearly defined regional signal.

The debate that you may hear among scientists is over whether the signal has emerged clearly or whether it is about to be. And that is the nature of that noisy debate. Most of what we are talking about is what we anticipate to happen in the time frame of the next 20 to 40 years when the signal should, if our theories are even remotely correct, become very, very audible and therefore we will be able to pick out exactly what the effects are.

And our argument is that an anticipatory society should try to guess what those are in advance. And if we can't confidently tell you, we can guess them, and they appear to have some potential negatives to try to slow them down.

Senator **Bradley**. This is the last question. I appreciate the time.

So, it has gone up in the last 120 years about a degree or 2.

Dr. **Schneider**. Fahrenheit, right.

Senator **Bradley**. Fahrenheit.

How much more does it have to go up in your judgment before we begin to see the kind of effects on the ocean or the drought scenario with the evaporation or whatever?

Dr. **Schneider**. The sea level, for example, is now—let me translate that—something in the order of 8 centimeters or so higher than it was 100 years ago based on the best reconstructions we can have. So, it is several inches up. And that is consistent with the kind of global warming. So, I wouldn't say that there have been no discernible effects, for example, in the global sea level.

The thermometers of the past decade apparently have told us that the 1980s are the warmest decade. We have had a number of rather nasty heat waves in the United States in the decade of the 1980s, in the Southwest in 1981, in the Corn Belt in 1983, in the Southeast in 1986, and now along the Missouri.

And I am not arguing that these are exactly caused by the greenhouse effect, but these are the sort of events we expect with increasing frequency as you warm up the temperature. So, it may already be observed.

Senator **Bradley**. But what is the answer? So, you are saying that we are already experiencing these things.

Dr. **Schneider**. The answer is that nature has a lot of variability, and the more of these events that occur, the less the chance is that they are occurring by accident.

Senator **Bradley**. Mr. Albritton, what do you say?

Dr. **Albritton**. Let me argue by analogy to the ozone-chlorine issue which has been studied over the last few decades and which my colleague, Dr. Watson, and I were involved in the U.S. delegation providing scientific advice on the Montreal Protocol. I think there is an interesting analogy that relates to policy questions involving chlorine and ozone and the greenhouse effect, and that is both of them have a time lag between the application of the forcing and the planetary response.

In the stratospheric ozone question, it is the time lag alluded to earlier of the time it takes these manmade chlorine compounds to reach the stratosphere and equilibrate in the stratosphere and reduce the chlorine.

In the climate issue, the time lag is due to, in part, the thermal time it takes to warm the ocean up.

Now, the importance of noting the analogy between those two is the following, and that is if we wait until we have unequivocal evidence that the predicted change is upon us, we are guaranteed in both issues that it will get worse before we can quit the game. That time lag is a very, very important feature of both of those issues. Let me explain what was done regarding that time lag regarding ozone. It might be instructive for policy considerations in climate.

At the time the Montreal Protocol was signed in late 1987, there as no evidence in hand fully scientifically accepted that ozone had been lost. The point here is that the Montreal Protocol rests on the strength of a theory not the observations of the effect. I think that is instructive from a climate standpoint because the same time lag is present, and that is I think the debate over whether a greenhouse effect is in captivity or not can be somewhat misleading. The debate should be over how confident are we in the theory that predicts that ultimately there is to be a warning.

And so, my recommendation for policy from a scientific standpoint is ask us how well we believe our understanding of the way the atmosphere works on these issues where the time lag means that at least perhaps some preliminary considerations have to be done, as was done in the Montreal Protocol before seeing evidence that the effect may or may not be fully upon us.

Senator **BRADLEY**. Does everybody at the table agree with that proposition that we have enough information combined with theoretical judgments that would argue for dramatic changes in behavior, industrial process, whatever needed to avert the more clear manifestation of the greenhouse effect?

Dr. **WATSON**. I think what Dr. Albritton said is that you clearly cannot wait for perfect knowledge otherwise you will be waiting forever. Therefore, I think there are some things that you can clearly do.

I would argue personally that even if there were no climate warming in the future, certain things on energy efficiency, energy conservation, make a lot of sense today. So, why not do them?

And so, I think what Dr. Albritton was saying, the way I would interpret it, we should move ahead in parallel looking at policy response strategies, implementing some policies where they seem to be necessary and improve the science simultaneously.

If we wait to see the observed global warming that many people have predicted, we will then live with that global warming for many centuries to decades. For example, the analogy with Antarctic ozone. Even if tomorrow there was a worldwide ban on fluorocarbons—the Montreal Protocol doesn't call for that, but even if there was, I would predict the Antarctic ozone hole will be there for another 50 to 100 years at least in the future. That is with the worldwide ban. With the Montreal Protocol, even ratified by all the nations in the world, I think we are committed to having the Antarctic ozone hole there forever.

And it is very similar in the global warming situation. Many of these gases that are predicted to cause a global warming have very long atmospheric lifetimes—nitrous oxide, the fluorocarbons, CO_2. Once up there, their consequences will be here for decades or centuries. Therefore, in many cases you will have to trust theoretical models, and we have to get as much circumstantial evidence as we can and direct evidence to support those theories.

So, I think the real message of Dr. Albritton, as I took it, was you cannot wait to see a large temperature change with consequences for sea level, agricultural productivity, natural ecosystems changing. You are going to have to have a combination of evidence such as global temperature trends, which are not perfect but certainly suggestive, and the theoretical models.

Senator **Bradley**. The last question I have. That answer would not be understood by any of my constituents. [Laughter.]

Who would be faced with higher electricity rates in order to deal with the situation or higher gasoline prices in order to deal with the situation. So, what I need to know from you, since you are the experts—or tell me two or three things that are happening now that are evident to more people than theoreticians that would lend some basis for why there has to be changes in behavior.

Dr. **Watson**. I'm not sure we should give you evidence of changes if we haven't got evidence for changes. The fact that we predict change, as we did in ozone, I believe is why people should be concerned. Scientific uncertainty is a thing that scares me more than absolute knowledge. The fact that we have said that climate could possibly change dramatically and quickly has me concerned. The Antarctic ozone thing came as a surprise.

What if the oceans have more than one state of ocean circulation? It could be they would no longer take up CO_2 at the rate they currently do. They might liberate CO_2 into the atmosphere. And then you would get a feedback mechanism by which climate would change at a much faster rate than we currently predict.

So, the thing is scientific uncertainty that a situation might arise that would be completely unhealthy is a thing that I think one has to get across to constituents. If I personally have not seen change, that does not mean to say I am not concerned. The fact that we might be moving in a direction—it might be of more drought or coastal erosion—is the sort of thing as a taxpayer that I should be concerned by.

Dr. **Schneider**. If I may use my in-laws as a metaphor to your constituents. The kinds of statements that get their attention have to do with sea level because they live in southern California. And when a storm goes by and there is a storm surge, which penetrates a certain distance inland, it is not hard to explain to them that that distance where they can't build along the coast where there is damage—that storm surge may be recurring every statistically, say, 25 years. And if you raise the sea level a foot, that it might be recurring every 15 years. That is intelligible I would think to most constituents, and they can understand that——

Senator **Bradley**. What would be recurring every 15 years?

Dr. **Schneider**. The flooding due to a storm surge. If you are going to have a storm go by that is going to make the sea level rise, say, 5 feet due to the pushing up of the water from both low pressure and the winds, that is going to go inland and cause substantial damage. Supposing you are starting the sea level at a foot or two higher, then the number of times it is going to go, say, a mile inland will be much more frequent then essentially. And that can have major economic and on-land use implications, and there may be a certain amount of insurance we would like to buy to slow that down.

Senator **Bradley**. Anything else?

Dr. **Schneider**. The current heat wave is another good example because although you don't want to argue that any one event is necessarily related to a global event like CO_2, it is the kind of event that almost certainly has to occur with increasing frequency if you are warming up the planet. Therefore, if we don't like heat waves of this magnitude, then we may very well not like a warmed earth. So, I think you can also have people relate to that.

Forest fires are another example. In warming and in dry periods, there is a substantial increase in the probability of forest fires. Indeed, a number of us are exploring whether that looks like another one of the outcomes in the future.

A fourth category is the United States agriculture has been a principal exporter for the United States both in terms of foreign exchange and in terms of world food supply. And one of the reasons we have been such a good exporter is because of the comparative advantage we enjoy from having a relatively benign climate. And, indeed, if the kinds of increases in heat waves that I had mentioned before occurred in Des Moines and in the Corn Belt, you might see a loss of our comparative advantage.

It was Dr. Roger Revelle, who is hardly a radical environmentalist, who proposed that loss of comparative advantage for U.S. markets might very well take place from the warming that would occur in higher latitudes in the Soviet Union and Canada opening up their production.

These are issues that might get average constituents to pay an insurance policy, I would think to slow it down.

Senator BRADLEY. Thank you very much.

Senator WIRTH. What you are saying is that what we are talking about in terms of this legislation are not radical steps. We are talking about energy efficiency. We are talking about long-term research and looking at alternative energy sources. We are looking at forestation. We are looking at population, things that even if the theories that you are talking about prove to be totally unfounded are items that we ought to do anyway, are cost effective and good for our national security.

Dr. SCHNEIDER. Certainly in my value system those are items that we ought to do anyway.

But one postscript on what Senator Bradley said earlier when he was suggesting that the science may be sufficient to justify action. I just wanted to make very clear—as a scientist, I have to do this and for my colleagues as well—that whether we should take action, of course, is a value judgment about whether we fear more in having the future descend on us with rapid change or whether we fear more investing present resources to hedge against that. In my value system, I believe in insurance. I am conservative in that sense. I think a little insurance that, as Senator Wirth said, also has high leverage makes good sense. But that, of course, is not a judgment that is scientific.

I remember hearing I guess about 15 years ago when I got started in this business an official of then ERDA tell us that we had 10 years safely to study this problem. I heard the same thing in front of then Congressman Gore's subcommittee in 1981 from a DOE official, and I am certain that we will be hearing that again and again. Indeed, it is not a scientific question as to how long one has; it is a value trade of about what you fear more. And in my value system, I thought your statement was perfectly appropriate.

Senator WIRTH. You have been very valuable. Your value system says that it is time for you to have a chance to complete your testimony, Dr. Albritton. [Laughter.]

STATEMENT OF DR. DANIEL L. ALBRITTON, DIRECTOR, AERONOMY LABORATORY, ENVIRONMENTAL RESEARCH LABORATORIES, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Dr. ALBRITTON. Thanks. I have also noted that most of my punch lines have passed by, but I will have the luxury perhaps of wrapping up.

Our laboratory in Boulder—this is NOAA's Aeronomy Laboratory—focuses on the chemistry and dynamical processes that relate to the earth's climate and air quality. So, it is a pleasure to be here to summarize not just some of their work, but the other NOAA laboratories that are around the United States.

I particularly appreciate the opportunity to discuss the global change in that regard, and I underscore the words "global change" rather than simply greenhouse effect because I think over the last 20 years with environmental crises right and left, one thing scientists have learned is that, in fact, the atmosphere—and the planet—is an integrated system and that we have begun to have to look at it as a whole rather than issue by issue.

As you had requested, I will focus my brief remarks on NOAA's research, that part that is aimed at the earth's climate and air quality systems. And the way I will do that is very briefly outline the scientific context into which those research efforts of NOAA are embedded. I will summarize the main thrust of some of its recent research. And lastly, I will sketch the plans that NOAA has for proceeding to try to answer or contribute to answering some of the remaining scientific questions that would be useful for policy.

In so doing, I will try to emphasize NOAA's interaction with other agencies because I assume that part of your questioning is to see if, in fact, there is an integrated or coordinated effort within the United States. I will also try to emphasize our connections with other countries because, as has been mentioned here several times, we are addressing a global problem that the global scientific and the global policy community must address.

I won't dwell long on the science background. We have alluded to many features of the earth's climate and global systems. I will simply point out that a useful analogy is to think of it as a climate machine, and that is it has a marvelous and bewildering variety of complex parts. There are inputs to those actions of the machine, and those inputs cause the machine to move to a different operating state, such inputs as changes in solar output, such inputs as greenhouse gases, and such responses as sea level changes or temperature changes.

The analogy with the machine is an interesting one, but it has one deficiency and that is our climate machine did not come with an operating manual. And as I see it, research of the last two decades has been to try to fathom how that climate machine works. And it is in that context that I will describe the efforts that have taken place within NOAA.

First of all, asking the question what is it on the planet that forces climate change; that is, what aspects of both the natural system and man's activities that could induce the climate to change to a new functioning state.

What NOAA has tried to focus on is, first of all, the well-known trace gas of CO_2. Its remote area observatories, the one in Mauna Loa, Hawaii in particular, is where the longest and most detailed data record of CO_2 change was taken.

It also is focusing on the other greenhouse gases beside CO_2, namely, those of methane and the CFCs that have been alluded to. By cooperation with other countries, it has instituted a flask sampling network whereby samples are taken at surface sites all over the world and returned to the main laboratory in Boulder for analysis. And I think by utilizing such a network, we now have a fairly global picture of methane abundancies and methane changes. And this is going to be particularly useful in unraveling this unusual gas methane in understanding why it has changed so dramatically over the last few decades and up to 100 years.

Well, the machine, as I indicated, has many and intricate parts. And we have tried to focus on understanding a few of those wheels and cogs of the climate machine. One is particular is stratospheric ozone, and I have mentioned a few aspects of that already. Let me just underscore that much of the stratospheric ozone work has been done in concert with NASA in focusing on several aspects of the system.

One of those is the Antarctic ozone issue that has been raised earlier. And that is shortly after the ozone hole was discovered in Antarctica, an airborne campaign was organized with NASA, NOAA and NSF in coordination to try to unravel the cause. And as I mentioned earlier, I think now we have a fairly good picture of that most unusual phenomenon.

My point here in bringing this example forward is that if you need or were to seek an example of smooth interaction between agencies with different research talents and different research interests, then I think the concerted effort to solve Antarctic ozone would be a good case study to roll out to indicate good interagency interaction.

Another process that I would like to cite—it has been alluded to here before—and this is understanding oceanic uptake of CO_2. That is the big reservoir for much of the CO_2 that we put into the atmosphere. And understanding its details will be very important. And I bring it forward because it has an interesting twist. Several NOAA scientists are using CFCs to understand how the ocean distributes heat and takes up CO_2, and that is the very compounds that threaten the ozone layer have a silver lining. And that is as they are taken up by the ocean, their ratio in the atmosphere is preserved. And so, by that dating process, one can determine where the water at the surface entered and how it is circulated through the deep ocean.

In terms of testing our understanding of the parts of the climate machine, one major part that we are coming close to getting our hands around is the 26 month oscillation in the tropics of the planet, the so-called El Nino southern oscillation. NOAA has explicitly tackled it in concert with many other countries and agencies as a small case study in climate that one has an opportunity to take apart in detail and understand one of those wheels and cogs.

Finally, in terms of predictions, NOAA has tried to emphasize the building of the models that Steve Schneider indicated. It has joined several other institutions, our sister institution in Boulder, NCAR, as well as the theorists in other countries, to try to construct a working facsimile of this machine that we call the climate machine. It may reside in a computer and it may be theory, but it is in fact a working model of the system. We know it is not perfect, but we know it describes many features of the planet.

The reason that these models are of utility is that they allow us to serve policy better; namely, we can run what-if scenarios. What if we do nothing, what would be predicted in the future? What if we decide policy option A, what would be predicted in the future? The completeness, the integrity and the defensibility of those global circulation models are a big part of NOAA's research.

In terms of future plans, there are several major unanswered questions, and they have been alluded to in the testimonies earlier. Let me just give some examples of the kind of focus that the NOAA labs are trying to bring to it.

First of all, we know now that CO_2 is not the only trace gas. And yet, we know that we must eventually predict a warming that would occur from all of the trace gases. And, therefore, a concerted effort to bring the understanding of methane, nitrous oxide and other gases up to par with that of CO_2 has been a major emphasis within NOAA.

In terms of climate processes, we have already mentioned the understanding of the mechanisms that created the Antarctic ozone hole phenomenon. And let me just mention one other process that is emerging now as a very important scientific point to be put to bed. Namely, sulphur is a natural emission of the ocean. These sulphur emissions as a gas have a tendency to form small aerosols, and small aerosols contribute to cloud formation, and cloud formation changes the temperature of the surface of the ocean. And so, here is a feedback loop involving natural emissions of sulphur from marine organisms that needs to be better understood so it can be fitted onto this machine that we are building as a model for the climate system.

In terms of tests of understanding, let me just mention one example. The focus on ozone has often been in the stratosphere, but it has two other major roles in the atmosphere. One is it is an infrared active gas in the middle atmosphere, but here at the surface, it is a very strong oxidant. And an aspect of global change that is receiving more and more attention, certainly in terms of some of the NOAA research, is to ask what changes have occurred in lower atmospheric ozone on the whole northern hemisphere as a result of natural activities and manmade activities, to institute a good monitoring system that can look at middle atmospheric and lower atmospheric ozone and to understand the processes of that.

Lastly, in terms of understanding how well we have built this replica that resides in our large computers of the climate system, an important point in guiding NOAA's research is that in order to test that understanding, which I think we must do before submitting its predictions to policy, we basically can't wait on the 100-year forecasts to take 100 years of data to see if we were correct. So, NOAA is making a very large emphasis on improving the data base that has existed over the past 100 years. We see this as the particularly fruitful way to test whether we have assembled a reasonable climate model, namely, do hindcasting with it. How well can the same model, whose predictions of the future that we will bring to you, reproduce the changes in the past?

In conclusion, I think I would echo the voices of the others who have testified here to say the following that the global climate system has changed substantially in the past and severely. We only have to look at records of ice ages, little ice ages, droughts, et cetera. There is no reason not to believe that such natural changes are going to continue into the future. There is now added to that the likely prospect that we will augment those changes with our own human-induced forcing functions.

There are two implications to all of that change, two policy implications, two science implications. With regard to natural variation—and it is a highly naturally varying system—the policy question is: Do we know enough about what institutes those natural changes to be able to accommodate it in a world of growing population? This is not asking what should we do to change things; it is asking are we smart enough to accommodate such events as the haunting images that we saw on television about the Sahel drought of the last decade.

The second point regarding human-induced change. The policy question there is different and yet it is equally valid. It is the one one hears the most, and that is do we understand the climate system well enough to take action at various levels about mending our ways for those parts that we may be causing. The policymakers will have to address both of those questions. Do we understand climate change in a world of growing population in order to better accommodate it? And secondly, can we identify the prospect that we may be inducing some of that change and take wise policy action? Scientists must assist with both of those answers.

Both answers require a fundamental understanding of the processes that are occurring on the planet, such things as the ocean-atmosphere couplings. And while we have a rudimentary knowledge of that system, there are many aspects that are pretty fuzzy.

An adequate insight certainly won't be easy to get intellectually or scientifically, and it will not be cheap. I think the fundamental understanding of natural processes that relate to the wellbeing of mankind are almost always cost effective. A comparison, for example, of a cost of a Sabin Salk vaccine shot to the economic and human suffering involved with an eye and lung shows what can be achieved when a real understanding of the cause of a thing is in hand. Regarding our environment, whether it be city air quality or global climate change due to greenhouse effects, it is really the price of ignorance that we can't afford rather than the price to gain understanding.

Thank you very much.

[The prepared statement of Dr. Albritton follows:]

TESTIMONY OF
DR. DANIEL L. ALBRITTON
DIRECTOR, AERONOMY LABORATORY
ENVIRONMENTAL RESEARCH LABORATORIES
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U. S. DEPARTMENT OF COMMERCE

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES

UNITED STATES SENATE

AUGUST 11, 1988

Mr. Chairman and Members of the Committee:

My name is Dan Albritton. I am Director of NOAA's Aeronomy Laboratory in Boulder, Colorado, which studies the chemical and dynamical atmospheric processes that influence the Earth's climate and air quality. I appreciate this opportunity to present NOAA's role in investigating global change, especially the "greenhouse effect" and its implications for global climate change to your Committee.

I will focus today on NOAA's current and planned scientific programs in climate change and in determining factors contributing to the "greenhouse effect," as well as international cooperative efforts.

SUMMARY OF THE SCIENCE

What is the Greenhouse Effect?

The average surface temperature of the Earth is established by how much of the incoming energy from the sun is retained by the planet rather than being radiated back to space. The re-radiated energy is infrared radiation, or heat. Most of this infrared escapes directly to space, but a significant amount is absorbed by gases in the atmosphere, like carbon dioxide and water vapor. This absorption is what is labeled the "greenhouse effect." The trapped energy amounts to 65 percent of the total our planet absorbs from the sun. Thus, the greenhouse effect is an important process in establishing the average surface temperature of the Earth. If there were no greenhouse effect, the Earth would be colder by about 33 degrees Celsius. Although the greenhouse effect is a natural phenomenon, human activity has begun to perturb it.

The Greenhouse Issue:

Human activity is changing the abundances of some of the atmospheric gases which absorb the infrared radiation. In response, the heat budget of the planet will also be altered.

The three most important greenhouse gases are water vapor, carbon dioxide, and ozone. Water vapor is the single most effective trapper of outgoing infrared radiation. Because of this, most of the radiation which escapes to space does so in the portion of the radiation spectrum in which water is a weak absorber, called the water vapor window. The problem is that anthropogenic actions are filling that window with other gases which absorb the radiation which would otherwise escape to space.

The most important of these gases which absorb in the window is carbon dioxide. The amount of this gas has been increasing due to the burning of fossil fuels and deforestation. The current annual increase is about 0.4 percent. The increased amount means more radiation is being absorbed in the window, providing more energy to warm the planet.

Recently, it has been recognized that other trace gases exist which behave in a manner similar to carbon dioxide. The principal ones are: methane, chlorofluorocarbons, ozone in the lower atmosphere (troposphere), and nitrous oxide. These gases are less important individually than carbon dioxide but their combined role in the greenhouse effect is comparable. Moreover, their abundances are also increasing and appear to involve human perturbation of natural processes as well, although they are not well understood.

NOAA'S ROLE

Current Activities:

For several decades now, NOAA has conducted research and monitoring programs to understand the climate system to better predict future climate. NOAA research programs include investigating the physical, chemical, and biological processes in the atmosphere and ocean to better understand the greenhouse effect and climate. NOAA also monitors many of the important atmospheric and oceanic variables using satellite and ground-based systems and makes data available to the research and user communities. NOAA monitors the atmospheric concentrations of various trace gases which contribute to the greenhouse problem. NOAA uses the observations and understanding of processes gained from its research activities to develop models which provide future climate scenarios. In addition, NOAA maintains the historical data base of worldwide climate information, providing a critical yardstick needed to measure future climate fluctuations. In concert with other agencies and the academic community, NOAA expects to embark on a broad program called Climate and Global Change in 1989. We believe the NOAA effort will represent one of the most comprehensive campaigns designed to understand these problems.

NOAA has been working on the climate issue for several decades through a number of programs. The NOAA Geophysical Monitoring for Climate Change (GMCC) program collects long-term measurements of atmospheric constituents at its four baseline stations (Point Barrow, Alaska; Mauna Loa, Hawaii; American Samoa; and the South Pole) and other locations. These measurements are used to determine how concentrations of gases and aerosols change with time and to identify the natural and anthropogenic sources and sinks of these constituents. The 30-year record of carbon dioxide taken at the Mauna Loa site has provided the world with the longest continuous record and shows the dramatic increase in concentration that has been occurring. As part of the Radiatively Important Trace Species (RITS) program, GMCC monitors other trace gases, such as methane, nitrous oxide, tropospheric ozone, and chlorofluorocarbons, which influence the greenhouse effect.

NOAA is also conducting research programs under RITS designed to understand the processes which are causing the abundances of the non-carbon dioxide greenhouse gases to increase. The program will also try to predict the climate and chemical consequences of the increased concentrations. The tropospheric photochemical cycles which form ozone from nitric oxide and nitrogen dioxide are being studied to understand the growing abundance of ozone in the troposphere. Source and sink measurements are necessary to understand the transport and removal of trace species in the atmosphere. Models are being developed which incorporate chemistry to try to understand the chemical and climatic consequences.

NOAA's marine laboratories are investigating the atmosphere/ocean exchanges of greenhouse gases and their distribution as part of RITS. The Atlantic Oceanographic and Meteorological Laboratory is investigating the distribution and chemistry of ozone, nitric oxide, and nitrogen dioxide. The Pacific Marine Environmental Laboratory measures the amount of carbon dioxide in the ocean as well as the atmosphere/ocean exchange of carbon dioxide. They also study the flux of dimethyl sulfide into the atmosphere to understand the role it plays in cloud formation.

NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) is a world leader in developing climate models. They have incorporated new understanding of the interaction between the atmosphere and oceans into a coupled ocean-atmosphere climate model which is being used to determine various climate scenarios, including those which include increased amounts of carbon dioxide. Dr. Syukuro Manabe of GFDL discussed some of these modeling results before this Committee on June 23, 1988. GFDL is also developing radiative and dynamic models which include the chemical processes defined in the RITS program to better represent their contribution to the change in the Earth's heat budget.

NOAA satellites are being used to determine several parameters of importance to climate change. The TIROS Operational Vertical Sounder (TOVS) measures water vapor content of the atmosphere. Another instrument measures atmospheric ozone. Information on sea surface temperature, important to interannual climate studies such as El Nino, is provided by infrared monitoring. The Earth Radiation Budget Experiment on NOAA satellites provides information on infrared radiation patterns as well as the absorbed solar radiation which helps determine the energy balance of the Earth. NOAA satellites are also the information source for global precipitation estimates, long-term snow and ice cover comparisons, and global vegetation surveys. NOAA scientists are processing GEOSAT altimeter data and providing near real-time sea level maps of the Pacific Ocean.

Future Plans:

The NOAA Climate and Global Change Program is scheduled to begin in FY 1989. This program will address observations, process studies, modeling, and information services to help NOAA provide better forecasts of future climate and is intended to provide decision makers with a reliable base of scientific information. We are interested not only in understanding the perturbations to the greenhouse effect, but many other factors which may act to alter climate. Programs NOAA is planning to begin in FY 1989 include: operational ocean monitoring of parameters influenced by seasonal to decadal changes in Earth's climate; monitoring of stratospheric constituents sensitive to changes in the stratosphere and coupling the observations to developing theory; continuing the Tropical Ocean and Global Atmosphere (TOGA) program to understand interannual climate variability (e.g. El Nino).

Questions NOAA needs to Answer:

Climate research has to consider both the natural variation of and human perturbations to the system. NOAA has a role to play in attaining an understanding of all the elements of the climate system. There are several areas which NOAA may participate in to determine climate response.

The forcing functions of climate are the changing natural and human input to the system, such as carbon dioxide and solar irradiance. NOAA could attempt to determine the quantitative properties of non-anthropogenic sources and sinks of carbon dioxide. The precision and accuracy of the current carbon dioxide trends should be calculated. The trend of carbon dioxide has been fairly well established, but the global trends of methane, tropospheric ozone, and stratospheric water vapor should be better understood. Since some trace gases, like methane, are functions of both anthropogenic and natural processes, ways to forecast future

The climate responds to these forcing functions by a variety of feedback mechanisms. Clouds are an important factor in the heat budget of the Earth. The gas, liquid, and solid phase processes which are significant in cloud formation should be understood. The entire coupling of stratospheric radiation, trace gases, chemistry, and temperature should be determined, as well as the coupling of climate variables to biogenic emissions of gases such as methane.

Experiments designed to test the understanding of the climate system and the processes within it should be developed to evaluate how well the system is understood. Part of this involves finding the major gaps in understanding of the El Nino patterns. Predictions of various processes should be tested against observations to see if they are consistent.

Predictions could then be made on how climate responds to the various forcing functions. In order to do this, the parameters most sensitive to climate change should be determined. The response characteristics to both natural variability and human perturbation should be discovered. Finally, scenarios of the range of climate states should be predicted for the next decades and centuries.

As a test for how well models may predict the future, the models could be used with past data to see how well they are able to "predict" past climate. In order to do this, the uncertainties in paleoclimate and historic data should be known.

Finally, we should determine how well we understand the aspects of climate change which will affect humans the most. This should include changes in sea level and extreme events like floods, droughts and severe storms.

NOAA INVOLVEMENT IN INTERNATIONAL PROGRAMS

The global nature of the climate system requires substantial international cooperation for the success of climate monitoring, research and prediction. Consequently, NOAA's programs are linked to those of other nations in both formal and informal interactions. Through international scientific meetings and working with visiting scientists, NOAA scientists coordinate research with scientists from around the world. In addition, a number of NOAA programs are planned in concert with international programs. For example, the NOAA RITS program is linked to the U.S. Global Tropospheric Chemistry Program, which, in turn, is part of an international Global Tropospheric Chemistry Program, under the auspices of International Council of Scientific Unions (ICSU). Similarly, NOAA's Climate and Global Change Program will be an extension of work conducted under the World Climate Research Program and will be part of the evolving national program in global change (including climate change), which is being coordinated with the International Geosphere-Biosphere Programme.

A model of international scientific cooperation in climate research is the TOGA program. This program involves scientists from North and South America, Europe, Australia, New Zealand and the Orient. Cooperative climate research with the People's Republic of China (PRC) is flourishing. The United States and PRC recently completed their fourth joint cruise in the Pacific Ocean under the TOGA program. In addition, the United States and India have agreed to studies of climate variability and monsoons, to be funded by the U.S.-India Fund.

NOAA also participates in the International Satellite Cloud Climatology Project (ISCCP). This project is designed to help determine the influence of clouds on the energy budget of the Earth. Data from both NOAA geostationary satellites are being incorporated into a global data base.

Under the U.S.-Soviet Environment Agreement, NOAA scientists are working in several areas of joint research with scientists from the U.S.S.R. related to climate. These include research and monitoring of stratospheric ozone, and a recent joint research cruise aboard a Soviet research vessel to study ocean-atmosphere chemistry.

As the principal federal agency responsible for U.S. representation to the World Meteorological Organization (WMO), NOAA is also involved in the international planning process for the Second World Climate Conference. This ministerial-level conference, to be sponsored by the WMO, the United Nations Environment Programme (UNEP), and ICSU, is planned for 1990, and has as its stated purposes "(i) to create awareness ... of the economic impact of climate and benefits from climate applications,

and (ii) to assess the current state of knowledge on the global issues of climate change and greenhouse gases, requirements for scientific activity and implications for public policy."
This second conference follows the First World Climate Conference, held in 1979 in Geneva.

Through its participation in the WMO, UNEP, and the Intergovernmental Oceanographic Commission, NOAA has access to global environmental data for both weather and climate forecasting as well as research purposes. Through its leadership role in these organizations, NOAA has been instrumental in improving the quality, reliability, and exchange of environmental data, much of which is collected by other nations.

CONCLUSION

Climate change can have a great influence on human society. Because of this, there is a critical need to improve both the knowledge base and international understanding and cooperation. NOAA can and will play an important role by gathering the information necessary to make objective predictions of future climate. The programs I have described today are a big step in this direction.

Mr. Chairman, this concludes my prepared remarks. Thank you for inviting me to speak to this Committee and I will be happy to answer any questions you or the Members of the Committee may have.

Senator WIRTH. Dr. Albritton, thank you very much. I thank all of you for being with us this afternoon. We have gone for now three hours. I suspect that everybody's tolerance for global warming may be—we may have exceeded that even more than walking into the afternoon will remind us of that.

The only closing comment I might make is to again register my concern with not the good, thoughtful analysis that we got from the EPA—and I am sorry that we didn't get a chance to talk more about the specifics of where we are going from here—but rather the response that we heard from the Department of Energy when they said to us, "Our policy is to resolve scientific uncertainty and to develop international cooperative effort." "Our policy is to resolve scientific uncertainty and develop international cooperative effort." It doesn't seem to me like much of a policy at all given what we have heard today, and given what we have heard over a great number of hearings on this issue on Capitol Hill, all of the evidence coming in from the scientific community about the fact that the globe is warming, all of the directions that are pointed by the scientific models.

It seems to me that as one great sage said we have heard a lot of platitudes of scientific uncertainty in order to avoid action. And I would hope that we can avoid that. And certainly it is my intent, and I would hope that as we move into this issue that we can get the information on this issue to the two campaigns this fall, and to see if we can get a greater sense of urgency that comes out of whoever becomes President in 1989 to really work with us in forging a much more aggressive approach so that we don't have platitudes, but rather real action that I think the very broad consensus is that we need.

Mr. Wayland, I want to thank you again and EPA. We have differed in the past over a lot of issues, but I must say your analysis today was very thoughtful and I know that there are certain constraints under which you all operate as well. But you did a very nice job, and I thank you very much.

Dr. Schneider, we appreciate your being here.

Dr. Watson, thank you very much.

Dr. Albritton, thank you and thank you particularly for your patience in being our clean-up hitter, so to speak. But we really appreciate your coming.

Thank you all very much.

The committee will be adjourned.

[Whereupon, at 4:58 p.m., the committee was adjourned.]

NATIONAL ENERGY POLICY ACT OF 1988 AND GLOBAL WARMING

MONDAY, SEPTEMBER 19, 1988

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 2 p.m., in room SD-366, Dirksen Senate Office Building, Hon. Timothy E. Wirth presiding.

OPENING STATEMENT OF HON. TIMOTHY E. WIRTH, U.S. SENATOR FROM COLORADO

Senator WIRTH. The Committee will come to order. Thank you all very much for being here today.

This summer a series of events have focused the attention of the nation and the world on the issue of global warming. Drought and heat waves gripped North America, the Mississippi River sank to the lowest levels since records have been kept, Bangladesh experienced severe flooding, and probably the most severe tropical storm in our history ravaged Jamaica and the areas of the Gulf of Mexico.

Scientific consensus has not developed about whether these events are the result of the greenhouse effect. However, scientists do predict that these kinds of events will become more likely and more severe in the future unless we act to slow down the emissions of greenhouse gases.

Similarly, the forest fires that have destroyed more than four million acres in the American West are a snapshot of what the future might look like in a warming world.

Droughts that reduced standing timber to kindling are serious enough in themselves, but the prospects of global warming also could threaten the health and productivity of forests in many other ways. Rapid climate change could outpace the adaptive capabilities of tree species.

And virtually all of our Federal agencies will have to examine what a future of global warming will mean to their mission, and to look for ways to help prevent our climate from changing dramatically.

Domestic forest policies could play a role in this effort. Trees and plants consume carbon dioxide, the primary greenhouse gas, during the process of photosynthesis. Today we will receive testimony on the prospects of domestic forest policies for removing some of the carbon that is placed in the atmosphere from fossil fuel combustion.

In addition, the chief of the U.S. Forest Service will outline for the Committee a new research program that has been developed at the Forest Service to examine the implications of climate change for forest ecosystems. This is exactly the kind of research that we will need in the future to better understand and plan for our future.

Global warming is probably the greatest political, economic and human challenge that we face, certainly for the remainder of this century, and probably well into the next. It is an issue that has vast and varied implications for the government, for the people of this country, and for the people of every nation around the globe.

We cannot afford to delay efforts to address the causes of this phenomenon, nor should we waste any time in implementing programs that will allow us to better understand the risks and improve the precision of our response. I am confident that today's hearings will provide information that will help us to move in this direction.

We thank you all very much for being here. Per our discussion with the witnesses, I promised Mr. Robertson that he ought to go first. And let us seek what—there are a number of Senators who have been very interested in this hearing and what it means.

And so, Dale, if we could start off and go with you, and then let us proceed from there. We thank you very much for coming.

And all of you are familiar with the rules of the Committee. We will include your statements in full in the record and leave the record open for other questions that may come from Members of the Committee, and your responses.

And I would ask that you summarize your testimony in whatever way you think would be most appropriate. And let us go from there.

[The prepared statement of Senator Johnston follows:]

STATEMENT OF THE HONORABLE J. BENNETT JOHNSTON

SEPTEMBER 19, 1988

I am pleased to welcome you to this afternoon's hearing on the Greenhouse Effect and domestic forest resources.

Testimony presented in hearings before this Committee earlier this summer contained sobering predictions regarding the severity and pace of global atmospheric change. Today's hearing will focus on one particularly alarming consequence of global warming for the United States, the impact on our nation's forests and related ecosystems. We will also closely explore methods for utilizing forest resources to reduce the rate of global warming related to carbon dioxide emissions.

Higher temperatures are likely to change the range and composition of domestic forests as we presently know them. As temperatures, frost patterns, and precipitation levels change, tree and fauna species may be subject to stresses such as insects and diseases that will jeopardize their continued survival.

Moreover, the recent devastating fires in Yellowstone and the Pacific Northwest provide a snapshot of what might transpire if the Greenhouse Effect continues to worsen. Syukuro Manabe, in testimony at June's hearings stated that under a warming scenario "soil will become drier over very extensive, mid-continental regions of North America". Coupled with increasing temperatures and significant declines in rainfall, fires on the order of this summer's may soon become the norm, dwarfing our present resources and capabilities to control their spread.

The American public's tremendous interest in this summer's fires has been overwhelming. Their continued interest in the future of our other national wilderness and forest resources should be assumed.

Although forests are likely to be potential victims of global warming, their role as possible solutions to atmospheric change must be clearly understood. As Dr. Dudek and Mr. Moll discuss in their testimony, large-scale domestic reforestation has been suggested as a means to remove carbon dioxide from the atmosphere and store it in the biomass of the forests. It appears that effective forest management policy may be an useful interim step to take in the reduction of carbon dioxide. We cannot afford to overlook a step which may prove economic in comparison with the potential for devastation under global atmospheric change.

STATEMENT OF F. DALE ROBERTSON, CHIEF, FOREST SERVICE, DEPARTMENT OF AGRICULTURE, ACCOMPANIED BY DR. WILLIAM T. SOMMERS, DIRECTOR OF FOREST FIRE AND ATMOSPHERIC SCIENCES RESEARCH, FOREST SERVICE

Mr. Robertson. Thank you, Mr. Chairman. On my right I have Dr. Bill Sommers, our Director of Fire and Atmosphere Sciences Research in the Forest Service. And with my prepared statement in the record, I would like to just briefly cover four points that I believe are very important.

Number one, forests and trees are very important in controlling the level of CO_2 in the atmosphere. In the photosynthesis process, trees convert CO_2, moisture, sunlight and nutrients into wood and give off oxygen. About the same amount of total carbon is stored in the woody parts of trees today as exists in the atmosphere.

This carbon that is stored in wood in the forests could eventually be released back into the atmosphere through decomposition or burning of wood.

So I believe an important strategy to slow down the warming trend, due to the increasing concentration of CO_2 in the atmosphere, is to plant more trees, keep them healthy, keep them vigorous and very efficient at converting CO_2 into oxygen, and then keep that carbon stored in the wood by not burning it or letting it decompose.

Mr. Chairman, if we could just increase the amount of carbon that is stored in the forest by 25 percent, we could offset the total increase in CO_2 added to the atmosphere since the beginning of the industrial revolution.

My second point is that forests are complex ecosystems that are likely to be significantly affected by climatic changes. Forests are some of the most complex ecosystems in the world. Everything is related: the vegetation, the fish, the wildlife, the streams, the water flow, and even insects and fungi.

All of these components of forests are sensitive to changes in moisture and temperature, especially the vegetation. Forest distribution, productivity, and growth rates are heavily influenced by the amount of moisture and the length of growing season.

For example, many areas of the West, which you are familiar with, go from sagebrush to Pinon Pine and Juniper to Ponderosa Pine with only very slight changes in the amount of moisture. As the vegetation changes, so will the kinds of wildlife change, and so will water flow.

As trees are subjected to additional stress, due to climatic changes, they become less resistant to insect infestations. In fact, it is well established that major insect outbreaks are correlated with weather patterns.

We have already seen the effects of drought this year on the survival of tree seedlings that were planted this past spring, as well as on forest fires. Many acres of tree seedlings planted this past year did not survive the summer drought.

Over four million acres of forest land have been burned thus far this year, and they have been burned with a greater intensity of fires.

Unlike annual agricultural crops, trees live a long time, a hundred years or more. Once planted, trees cannot be shifted around to reflect changing weather patterns.

So we need to be able to grow and manage trees with a tolerance to withstand changing weather conditions or climatic changes over the long term. Otherwise, there just would not be an incentive to plant trees for the landowners, if the trees are not likely to survive until they mature.

The third point I would like to make is we do need to know more about the potential effects of climatic changes and then how we can build more tolerance into the ecosystem to withstand those effects.

Unfortunately, most of our knowledge base about forestry is based on research that was conducted under existing climatic conditions, which have been relatively stable over the past 50 years or so.

If climatic conditions change, then many past assumptions upon which research studies were based are no longer valid. We will either have to adapt existing research conclusions to changing climatic conditions or conduct new research.

Basically, we need to know more about how the forest will respond to changing climatic conditions and then to figure out how to incorporate that new knowledge in the future management of the forest.

Since trees are a partial solution to the CO_2 problem, we also need to know how we can better manage the forest to improve atmospheric conditions. This research need not wait until the atmospheric scientists determine or figure out how climatic conditions will change.

Forest scientists need to be at work now to determine how we can best respond to the predicted changes in weather patterns.

My final point is that the Forest Service has a lot of capability and experience that ought to be used in dealing with this important problem. The warming trend and the associated changes in weather patterns are global problems that require a comprehensive interdisciplinary research program, and the size of that problem spans the mission and responsibility of many Federal agencies.

Because of the strong relationship between the atmosphere and the forest, I believe Forest Service researchers have a lot that they can contribute toward this problem.

We have a large research organization in place with over 800 scientists located throughout the United States. We have, I believe, the longest-term baseline ecological data on 83 experimental forests around the country which, for example, have been extremely useful in acid rain research. The first experimental forest was established in 1903, and the first study conducted in 1910.

The Forest Service also has 189 research natural areas where ecological research is being carried out. Mr. Chairman, the Forest Service has a unique database that has been extremely useful in our acid rain research. I believe it will be equally useful in our forest-atmosphere relationship research.

The Forest Service is very much involved in research on acid rain and the assessment of acid rain, which is scheduled to be completed in 1990.

As we wind down the acid rain assessment work, we plan to shift the cadre of about 75 scientists currently working on the acid rain problem into a more comprehensive research work program dealing with forest health and productivity in a changing atmospheric environment.

This will broaden our research efforts beyond just the effects of acid rain on forests to include other atmospheric changes.

In conclusion, the Forest Service has a lot of talent and experience in both the research and the management of forest ecosystems.

We are already moving out in our research program on the effects of atmospheric changes on forests. I believe the Forest Service has much to contribute toward managing these problems over time.

[The prepared statement of Mr. Robertson follows:]

STATEMENT OF
F. DALE ROBERTSON, CHIEF
FOREST SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

Committee on Energy and Natural Resources
United States Senate

Concerning the Effect of Global Atmospheric Change
on Domestic Forest Resources

September 19, 1988

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE:

Thank you for the opportunity to participate in this hearing on the effects of global warming on domestic forest resources. I am accompanied today by Dr. William T. Sommers, Director of Forest Fire and Atmospheric Sciences Research.

We share your concern about the potential environmental effects that would take place if the global atmospheric change does occur. We believe that research by Forest Service scientists can contribute to the body of knowledge related to these potential effects.

Because trees grow very slowly in comparison to other plants, they cannot adapt to change quickly. Thus, they are quite sensitive to even small, long-term changes in their environment.

For example, forests growing on the east front of the Colorado Rocky Mountains are particularly sensitive to temperature and moisture changes. Trees growing at high altitudes are limited in their distribution by temperature, while trees growing at lower altitudes are limited by moisture. If either temperature or moisture changes, then the distribution of tree species growing at the temperature and moisture margins of high and low altitudes will change.

FOREST RESOURCES AND CLIMATE

Forest resources are closely tied to climate and, thus, we are concerned about the potential direct and indirect effects of climate changes that may occur as a result of increased carbon dioxide levels. If these changes do occur, there could be increased numbers of forest fires, decreased water levels in the West, increased susceptibility of forests to insects and diseases, and changes in fish and wildlife habitats.

Scientists do not yet agree on the causes of the severe drought in the Midwest or other effects of unusual weather during the past couple years. We know, however, that the drought of the last several years is having a serious effect on our forest resources. The most dramatic effect has been the intense fire seasons during the last four years. The drought is also having other effects on our forest resources. Reforestation gains are jeopardized because planted seedlings are being killed or severely stressed by drought conditions. Drought-stressed trees are more susceptible to insect attack, and we are seeing significant increases in pine beetle activity in the South and the West. Stream flows and impoundment levels have fallen in many affected areas, adversely impacting recreation, fishery, wildlife, and watershed resources.

A serious potential effect of a change in our world's climate would be changes in tree growth and yield. This would affect the level of sustainable timber harvest for various tree species. Distribution of tree species would also be affected. Such changes in tree growth and yield, sustainable harvesting levels, and in species distribution would affect the economy of large portions of the South and the West. Changes in recreational use patterns could also be affected.

FOREST SERVICE RESEARCH

Forest Service Research is uniquely prepared to provide the expertise, the experimental sites, and the monitoring and data sources needed to address the complex effects of climate change on our forest resources. We have over 800 scientists at 9 Research Stations and 72 field laboratories located from Alaska to Puerto Rico and from Maine to the Pacific Islands. Our scientists work on the longest-established experimental forests, watersheds, and ecological research sites in the world. These sites range from the taiga of Alaska, to heights of the Rockies, to the tropical forests of Puerto Rico.

In terms of scientific disciplines we have ecologists, atmospheric scientists, foresters, geographers, wildlife biologists, fire scientists, and other skills that are needed for this research. Our scientists have strong working relationships with colleagues at the National Center for Atmospheric Research, the Environmental Protection Agency, the National Science Foundation, and universities throughout the United States and in some foreign countries.

PLANNED PROGRAM OF RESEARCH

Even more important than our capability to do research on the effects of global climate changes is our carefully planned program of research. Let me tell you a little bit about that.

To begin with, the program recognizes that much of the knowledge we use in modern forest management is based on the stable climate we have experienced so far in this century. Any significant change in climate will likely be associated with unstable, highly variable weather patterns that will require a major revision and updating of that knowledge base. Because climate change will mean shifts in regional and seasonal precipitation patterns, we can expect changes in the structure and composition of our forests.

Trees are a solution to the problem of global warming, because they take up large amounts of carbon dioxide from the atmosphere.

However, there are many unknowns, uncertainties, and questions. We need to know how changes in the climate will affect our forests. We need to know how our forests affect the climate. And we need to know how we should manage our forests in view of potential climate changes.

The Forest Service is in an excellent position to answer these points. We have 80 years of experience in managing our forests, and we have the long-term data base from our research on forest ecosystems that will be needed to help us prepare for climate change. With these answers, we will be better prepared to manage the nation's forests and rangelands as they respond to the predicted effects of global warming.

Mr. Chairman, this concludes my statement. I would be happy to answer questions from you or other Members of the Subcommittee.

Senator WIRTH. Thank you, Mr. Robertson. Mr. Sommers, is there additional information that you might like to add from the perspective of your set of responsibilities within the Forest Service, or your particular project, which I understand has been going on for some time now, of long-term forest plans?

Dr. SOMMERS. Yes, Senator. The Chief in his testimony related the history that the Forest Service has had over recent years in acid rain research and the long-term history of ecosystem-based research.

For about the last 3½ to 4 years we have been in a rather intensive planning mode to look at the whole picture of atmospheric change, including global climate change as it affects forest ecosystems and how forest ecosystems can help ameliorate the problem.

What we have done is in preparation for the completion of the NAPAP assessment in 1990, to see what we should fold that program into. We have developed a rather comprehensive research program for the future from an ecosystem viewpoint, which will include effects of physical and chemical changes of the climate on forest ecosystems, and how forest ecosystems interact with the atmosphere to ameliorate some of those changes.

Also, I think an important part of our program is that we do affiliate very strongly with the larger part of the Forest Service, which is the Land Management Agency. Many of our research applications come to fruition in managing the land and managing the forest resources. This is in contrast to those agencies that operate in strictly a regulatory atmosphere.

So we have a plan and we have the resources. We would like to focus on this work in the future.

Senator WIRTH. Chief Robertson, let me ask you, can you tell us, looking long-term, if in fact the theory of global warming is accurate as many of us believe it is?

And that if what we have seen this summer is an indication of what the future will look like, unless we make changes in fossil fuel policy, energy policy, population and all the rest, do you have, have you done work on what you would project is going to happen in terms of forest fires on the North American continent if there is a dramatic increase in the temperature, as we have seen this summer?

Mr. ROBERTSON. Well, I think this summer is a good example of one of the driest years on record. And it has been hot and dry. We have experienced——

Senator WIRTH. Would the global warming phenomenon be reflected in hot and dry forests?

Mr. ROBERTSON. Yes, it would.

Senator WIRTH. So what we have seen this summer is what the future would look like?

Mr. ROBERTSON. Yes. What we do not know is if this summer is just a normal cyclical weather pattern or a part of a bigger trend.

Senator WIRTH. But if it is, we could anticipate this sort of summer that we have seen would be more the norm than not, is that right?

Mr. ROBERTSON. I would say so, yes.

Senator WIRTH. OK, go ahead, sir. I just wanted to put that in the context that this is in fact sort of a case study of what the future might look like, if in fact global warming occurs.

Mr. ROBERTSON. Yes. I have already talked about the major forest fires out West, of very intense burns that burned a lot hotter than normal forest fires. They spotted in the Yellowstone area 1 to 3 miles ahead of the major fires, which made them very difficult to control.

We are looking forward to—we are not looking forward to it, but we are planning ahead that the stress that is put on the trees this year because of drought has weakened those trees. We expect major increases in infestations of bark beetles next year because of the weakened condition of the trees.

Senator WIRTH. So what we have seen in this summer in terms of forest fires we can with relatively good probability predict for the future?

Mr. ROBERTSON. Well, if the weather conditions are similar to what we had this summer, yes. This would be a good illustration of what could happen.

Senator WIRTH. And what does that then tell us we ought to be doing in terms of the policies of the Forest Service in terms of forest management today?

Before we even get to the long-term activities that Mr. Sommers was talking about, what does that tell us we ought to be doing today?

Mr. ROBERTSON. Well, it is hard to tell how we ought to change our management of the forests until we get more research available.

But we simply are going to have to try to manage for a more vigorous, healthy forest to withstand the additional stress that would be put on the trees as a result of climatic changes. We worry a great deal about fire. That means we need to do some things in terms of putting the forest in a better condition so that we can deal with major catastrophic fires; for example, firebreaks and reducing the fuel level in the forest.

Senator WIRTH. What is the size of your budget this year?

Mr. ROBERTSON. The total budget for the Forest Service is about $2 billion.

Senator WIRTH. What percentage of your budget is focused on the kinds of activities that are going to be necessary to better manage the forest in terms of potential increased dryness and fires and so on?

Mr. ROBERTSON. Well, our fire budget is about $160 million. But then we are spending another $300 million this year under emergency firefighting. So the total firefighting bill is going to be almost close to half a billion dollars.

Senator WIRTH. Half a billion dollars?

Mr. ROBERTSON. Half a billion dollars when you put Interior agencies and the Forest Service together, with both emergency firefighting and our regular program.

Our research program is about $140 million. I would say about 15 to 20 percent of that research could be related to problems associated with the warming trend and possible climatic changes and their effects upon the forest.

Senator WIRTH. Let me just ask two other quick questions. Some other Members of the Committee have arrived, and I want to give them the opportunity to ask questions as well.

In your summary testimony you talk about a warming trend due to increasing concentration of CO_2 in the atmosphere. One of the things we ought to be doing is to plant more trees and to keep them healthy, fast-growing and efficient, and converting carbon dioxide into oxygen.

Do we have a program under way to do that? And how much would that cost to do that? Theoretically, that is right. But what are we doing about that?

Mr. ROBERTSON. Well, the solution to that problem is one that a lot of people do not like. But we need to replace old forests that are inefficient in converting CO_2 to oxygen with vigorous, fast-growing forests that convert more CO_2 to oxygen.

In other words, there is almost a direct correlation in how much CO_2 is absorbed and how much oxygen is released in a forest with how much wood is growing in that forest. A fast-growing young forest is more efficient than an old, slow-growing forest.

Senator WIRTH. And how would we go about increasing the amount of carbon stored by 25 percent, as in your testimony? How do we do that?

Mr. ROBERTSON. Grow more wood and do not let it burn up or decompose.

Senator WIRTH. And does that mean replanting a lot of areas? Does that mean planting a lot of Federal lands that are open space in the country? Does that mean a major reforestation program of hundreds of millions of trees across the country?

Mr. ROBERTSON. I think reforestation is one of the best things we can do. We set an all-time record in reforestation this past year. I believe it was about 2 million acres.

One program that has been very helpful is the Conservation Reserve Program, under which over a million acres of marginal farmland have been converted to trees. That has got to help in reducing CO_2 levels.

Senator WIRTH. Now again going back to what is in your budget. You have a budget of $150 million in the research area, and that includes these reforestation efforts?

Mr. ROBERTSON. No. Our reforestation effort on National Forest lands is around $200 million.

In our state and private forestry budget, we also have some money to assist, both technically and financially, private landowners in planting more trees. Again, the Conservation Reserve has been a big plus in planting trees.

Senator WIRTH. Finally, what comments would you like to make on the so-called "let burn" policy?

There has been an enormous amount of discussion by a lot of Monday morning quarterbacks, it seems to me, about the policies of the Forest Service and the Park Service. And it seems to me that you probably have something you would like to say on behalf of the Forest Service related to the current fires and the "let burn" policies.

So my final question would be whatever you would like to say for the record on that point at this time.

Mr. **Robertson**. I am glad you gave me the opportunity. First, we do not have a "let burn" policy. And then I will footnote that.

For most National Forest land, we have an aggressive fire-suppression program. We attack a fire as quickly as we can to put it out. Now, there are a few exceptions to that in certain wilderness areas, where we have to rely upon fire over time to help manage the fuel load.

As trees grow, they are building up fuel. At some point in the future that fuel is going to burn. So in certain wilderness areas we have gone in and made a detailed fire analysis of what kind of fire we would like to see go through the wilderness and under what conditions.

We have prepared a detailed prescription of the conditions under which we would let a fire burn in that area. If a fire starts in that area, if it is within the prescriptions, and if it is meeting certain management objectives for that wilderness area, we do not always take a strong aggressive action to put it out. Instead, we try to manage it.

Another important point is that, if there is any doubt in our mind that the fire is going to get out of prescription and escape out of the wilderness areas and threaten other property, we take immediate action to try to put that fire out.

Now, there was some miscalculation this past summer. Some fires got out of wilderness areas and threatened some private property and threatened some National Forest lands outside of wilderness areas.

As I have said on TV several times, in hindsight we would have backed up and treated those fires differently. The few that we had in wilderness areas should have been put out as quickly as possible.

But of the fires that got away from the Forest Service, one of them burned for about a day and a half to two days before we tried to put it out. The other one was less than two days in the Yellowstone area.

Senator **Wirth**. Thank you, Chief Robertson. Senator Nickles.

Senator **Nickles**. Chairman Wirth, thank you, my questions are on the same line. I had some concerns as I flew over part of the Yellowstone area this summer when it was burning out of control, despite the efforts of the Forest Service. And I guess it concerned me.

I also talked to a few people in the Forest Service and others that indicated that they felt like aggressive efforts should be made to put out fires in the wilderness areas. Would you agree with that?

Mr. **Robertson**. In most cases we would. As I just explained, there are a few cases where we would make an exception to that.

Senator **Nickles**. In the case where you have fire in a wilderness area, do you use all available techniques to put out the fire? In other words, do you use mechanical equipment, et cetera, to put out the fire in wilderness areas?

Mr. **Robertson**. Yes. We use bulldozers or whatever we need to, if we think that is what is needed to put the fires out.

Senator **Nickles**. How many acres have you lost?

Mr. **Robertson**. Well, nationally there is about 4 million acres that have burned in total so far this year. In the Yellowstone area, it is about 1.6 million acres. I think about 1 million of that is in Yellowstone National Park.

Senator NICKLES. Now, of the 4 million acres, do you have a rough dollar figure of how much money you are talking about in commercial timber, et cetera, that is lost?

Mr. ROBERTSON. Well, the big cost is the firefighting bill. We are probably running close to $300 million in firefighting costs this year.

Senator NICKLES. Just a second. I thought I heard you state earlier that you spend about $500 million.

Mr. ROBERTSON. There is about $300 million of emergency firefighting, and then our regular budget has about $160 million in it in terms of hiring fire crews and getting our pre-suppression and firefighting force in place.

Once we have a fire then we spend emergency firefighting funds which have been about $300,000.

Senator NICKLES. If you add it all together, it is close to $500 million. Is that correct?

Mr. ROBERTSON. Yes. And then back to your question. Timber values in the Yellowstone area have not been too great, but the timber values we have lost have been crucial. Most of the burn was in Yellowstone National Park or in wilderness where we do not harvest timber and where we will not salvage that timber.

But the fire got over on the Shoshone National Forest, just west of Cody, where it burned up some valuable timber land that is very vital to the local industry.

Senator NICKLES. What about the wildlife?

Mr. ROBERTSON. None of us would ever want to see that much area burned at one time. That size of burned area, 1.6 million acres of the Yellowstone area, is going to have, I believe, a major disruption to the wildlife.

A lot of the winter range, for example, for the big game was burned up. That is going to be a problem this year, taking care of the big game. I think we are probably going to have a proliferation of some of the big game animals, especially elk, over the next 2 or 3 years, because we are going to have more summer range.

After the forest is burned, the new growth of grasses and brush is very good food for the big game. So I think we will see many changes in the populations of the various animals as a result of this 1.6 million acre burn.

Senator NICKLES. Were that many animals destroyed in the fire?

Mr. ROBERTSON. I doubt that if many animals, at least big game animals, were destroyed in the fire. I think there has been a report of a few bear and a few elk killed. The problem is not the animals that were destroyed in the fire but rather the winter feed for them.

Senator NICKLES. And is that going to be more positive than negative?

Mr. ROBERTSON. Any time this much disruption of wildlife habitat occurs, some species are going to be hurt and some species are going to flourish on the situation.

If we can bring those herds of animals through the winter with some winter feed, it will probably be beneficial.

Senator NICKLES. But you are going to have to scurry around, trying to find winter feed?

Mr. ROBERTSON. Well, yes. The problem now, yes, is how we are going to bring the winter herd through this winter.

Senator NICKLES. The purpose of the hearing is to talk about the effects of carbon dioxide emissions and the problems.

And I heard your statement that one of the solutions to that problem would be to increase the amount, I guess, of growing forests, and you mentioned your efforts there. What effect was the fire—when you lose 4 million acres to the fire, what does this do to carbon dioxide emissions?

Mr. ROBERTSON. There was a lot of carbon that was stored in those trees and that wood was burned up. The carbon dioxide went back into the atmosphere.

Senator NICKLES. So it increased or exacerbated the problem?

Mr. ROBERTSON. Yes. It increased the carbon dioxide in the atmosphere.

Senator NICKLES. Would you concur with the statements of others that we do have a serious and significant problem with carbon dioxide emissions today?

Mr. ROBERTSON. Well, the scientists ought to answer that. But I think the scientific evidence is that we are having an increase in CO_2 in the atmosphere, with about a 25-percent increase since the beginning of the industrial revolution. That increase is changing the temperature of the earth.

As temperatures change, weather patterns are also going to change. How that is all going to play out, I do not think the scientists can predict yet. But I think there is general agreement of the warming trend.

Senator NICKLES. But you do not have at least a conviction whether that is all that negative or conversely positive?

Mr. ROBERTSON. Well, it is going to change the weather patterns, and the temperature is going to change. There will probably be variations according to different places in the country.

The precipitation patterns are liable to change. How they will change, nobody knows. But the point I made in my testimony is that forests are very sensitive to changes in moisture and the pattern of precipitation. If the pattern of precipitation changes, we will see changes in the forest.

Senator NICKLES. Thank you very much. Thank you, Mr. Chairman.

Senator WIRTH. Senator Wallop.

Senator WALLOP. Looking at the firefighting efforts in the Teton this year, I have to say that I really think they were sort of schizoid.

It is true that when the fires started in the Teton wilderness, after an initial hesitation, they did come in with helicopters and began to fight the fire. But they began to fight it with what is called a "light hand on the land" policy.

And I was told when I went there in late July, and before it had gotten out of the Teton wilderness and into Yellowstone Park, though it was powerfully close to Yellowstone Meadows at the time, that they were very reluctant to let people use chainsaws.

They had them up there, but it seems to me that that is a sort of way of impeding. I mean if they cannot use them then that is just one more thing to carry. And it strikes me that one of the things that ought to come out of this is a certain more purposeful and less hesitant approach.

If it is burning within prescription, and I understand that, especially in the wilderness there, fine, although I must say that from this point of view prescription ought to be able to take into account the given circumstances that nature provides you on a given year.

And at the time, Teton County had applied for, or was at least a large portion of it was trying to persuade the county to apply for drought disaster designation. That would have tended to indicate that whatever the spring may have been like, the summer was not going well.

But even then, I think what Wyoming, what people that love those forests and surround them would like to see is a less hesitant, more confident approach. If it is time to fight it, by all means, with everything there is, fight it. If it is not time to fight it, then keep people informed and watch it.

But that ambivalence did your efforts no good in the minds of the public, and in fact did not really very much good in that big fire, which is still one of the biggest of the five that are up there. Would you disagree with that?

Mr. ROBERTSON. I agree with you.

Senator WALLOP. The other thing, I mean it is too late by any stretch of the imagination to go over those roads again.

But with that blowdown, some of us did forecast fire consequences, which materialized. And it does not seem to me still as though it would have been a bad thing to at least minimize that fuel loading with a light salvage of what could have been taken out of there.

I am sure that—you know, I can already hear the environmental press saying, that is a bad precedent. But I am not certain that it is a worse precedent than the one we have just been through.

Now, when you say that you could increase the net average annual growth of forests by almost two-thirds, you are really saying that you ought to manage those terminal stage timber areas, to harvest them, to plant in them and to reforest them at the end, are you not?

Mr. ROBERTSON. Yes. That is one way to reduce the CO_2.

Senator WALLOP. And that is why you are saying it may not be popularly received but it would be the most effective way of dealing with those older diseased or terminal stage forests?

Mr. ROBERTSON. I think one statement I made in my testimony was, if we could increase the amount of carbon that is stored in trees by 25 percent, and that is certainly within the realm of possibility, we could offset the total added increase of CO_2 in the atmosphere since the beginning of the industrial revolution.

Senator WALLOP. I hope what you say is heard. I mean, I really do.

When people talk about the low-cost timber sales, I wonder what they now judge the relative merits of that might be. I have never quite subscribed to that theory, I might add now, because the mechanism by which the accounting takes place is, I think, very suspect.

But just for the moment, granted and say that they are such a thing, it would appear to me pretty cheap on the basis of the four million acres and the amount of money you spent fighting fires this year, if even half of that could have been managed for fuel loading and for CO_2.

Mr. **Robertson**. Well, those 1.6 million acres that we burned in Yellowstone certainly a below-cost fire situation.

Senator **Wallop**. Well, I do not know anybody around who thinks that we might have timbered Yellowstone. I mean, certainly this Senator would not have ever thought that.

When I read the policies, at least the Park policies on "let it burn," it sounds as though something much more on purpose is taking place than happened.

It sounds as though, if something is within prescription, it is within prescription in the kind of forest that is in terminal stages. And not that utterly asinine distinction that if a man starts it you put it out and if God starts it you let it burn.

I mean, that just does not sound like anybody is paying heed to the store. I just would ask you, when you say within prescription in the wilderness areas, do you make that distinction between man-caused and natural fires?

Mr. **Robertson**. I do not.

Senator **Wallop**. Well, I know you do not. What about the forest supervisors? Because that is kind of what it sounds like, at least to the public. And I think that is probably where the course of hearings may ultimately go, is to what is the decision?

Mr. **Robertson**. To me, whether it is man-caused or lightning-caused is immaterial. If there are benefits to a fire in these wilderness areas and the fire is within the burning conditions set for it, we ought to let those benefits govern our decision-making process rather than how the fire got started.

Senator **Wallop**. Mr. Chairman, I thank you. I think we hear a little bit at least, and I hope there is reforestation in mind in some of these burned areas.

Even perhaps, I know that may be outside the realm of possibility for them.

But even perhaps in the wilderness areas, I think the reforestation in these circumstances would not be a bad thought. And I thank you.

Mr. **Robertson**. Well, I might add, Senator Wallop, that both Secretary Lyng and Secretary Hodel are putting together a review team of the fire policy. And that team will look at some of the very things you brought up.

Senator **Wirth**. Thank you, Senator Wallop. Senator Murkowski.

Senator **Murkowski**. Thank you, Mr. Chairman. Let me commend you on the importance of this hearing in the application of atmospheric accumulations of pollutants and global warming trends and what it may or may not mean.

I sincerely hope that from this hearing we get some factual information so that we can make decisions based upon some scientific knowledge rather than emotion, which is often the case.

I would like to pose just to Dale Robertson, with regard to the forests in Alaska, and particularly the Tongass National Forest. As you know, Chief, we have about 17 million acres in the Tongass National Forest, only 1.7 of that 17 million acres are scheduled for harvest over a 100-year span.

Technically I think it is safe to say that approximately of the entire timbered commercial area in the Tongass National Forest, two-thirds have been set aside in wildlife and wilderness and non-timbered restrictions, leaving only approximately one-third of the commercial forest available for harvest, and the recognition that the productivity of the forest sites have had a very high regeneration rate.

Yet it is our understanding that unless an area has been cut over 50 percent of the biomass may be dead or dying at any one time. Yet when an area has been cut over, the trees appear to be coming back two or three times the volume, depending on the forest management practices.

And under these conditions, it appears that perhaps we could best address a global warming problem through a sustained timber yield management concept, which would transform some of the old, dead and dying trees in the forest, avoiding the release of carbon dioxide produced in the natural decay process, and regenerating with young, fast-growing healthy trees which act as a sink for atmospheric carbon dioxide.

I am wondering, Chief, if this is a consideration in the management of our national forests and particularly in the Tongass National Forest, which is the largest?

Mr. ROBERTSON. Well, the points you make are accurate, that a new, young, vigorous forest is much more efficient at converting CO_2 to oxygen than the old growth forest that we have in Alaska. We can increase the efficiency of that forest by converting it to younger forest.

But I would have to say in the process of revising the Tongass Land Management Plan, that factor has not been taken into account in our decisions.

Senator MURKOWSKI. Is there any reason why it should or should not be? Or is it simply a question of addressing what appears to be a situation we should become concerned in as far as forest management practices?

Mr. ROBERTSON. Well, I think it is a factor, like a lot of other factors, that ought to be taken into account.

But again, looking at the size of the Alaska forest in relation to the total problem we have, it probably has a minor effect on the global warming trend. But Alaska, nevertheless, is part of the forests of the world, and we need to worry about all the forests throughout the world in order to reduce the impact.

Senator MURKOWSKI. My last question is, Mr. Chairman, Can you give us the distinction, Chief, on the issue of clearing a forest for the ultimate objective of having tillable land, as opposed to harvesting of forests with the idea of regenerating it with a like forest, and the aspects of those two applications of principle on the global warming trend?

Mr. ROBERTSON. Forest land is converted to agricultural land or to grass, the capability of the forest for reducing the amount of CO_2 will be affected.

On the other hand, if that land is converted to a younger, more thrifty forest, then the capability to reduce CO_2 levels will increase.

Senator **Murkowski**. Is there any application of convertibility in the Tongass to tillable as opposed to regeneration of utilization as a continued forest?

Mr. **Robertson**. I am not sure I understand the question.

Senator **Murkowski**. Well, my question is, Are they logging it to use it for other agricultural purposes? Or are they logging it with the idea of regenerating it as a forest?

Mr. **Robertson**. I have been to Alaska several times, and I do not think I have ever seen any forest cleared for the purpose of converting it to tillable or agricultural land. It is cleared to convert it to new forests.

Senator **Murkowski**. Thank you, Mr. Chairman.

Senator **Wirth**. Senator Evans.

Senator **Evans**. Thank you, Mr. Chairman. Let me continue along the line of the old growth versus new growth, and the questions from Senator Murkowski were aimed at the Tongass.

Speak in more general terms. At what point in the life cycle of the forest, and let us take the typical hemlock and fir forest in the Northwest, is there any evidence, I presume there is, that would give us sort of a curve of efficiency with which a forest produces oxygen and uses CO_2, compared with the age of that forest?

Mr. **Robertson**. I think those are fairly simple relationships. The more wood you grow, the more CO_2 you use in growing that wood.

Senator **Evans**. But the forests from age zero to age 100 or age 200 has a different growth rate in the production of wood, I suppose.

Mr. **Robertson**. There is a term we used in forestry called cumulative annual growth. In other words, the growth curve goes up like this, and at some point it levels off. At that point where it levels off is the accumulation of annual growth.

In the Doug fir-hemlock forest that you talked about in western Oregon and Washington, that is probably around 70 to 80 years.

Senator **Evans**. It levels off as age continues. At some point does it actually start downward?

Mr. **Robertson**. Yes. I think a lot of the old growth forest that we have in the Pacific Northwest is in a negative situation. We are losing more wood through decay than we are growing.

Senator **Evans**. So the combination of windfalls and decay and whatever disease there might be exceeds the growth in the remaining healthy timber?

Mr. **Robertson**. Yes. I was forest supervisor of the Mount Hood National Forest, and I had a lot of old growth. It was not uncommon to have a timber sale where 50 percent of the wood was decayed and was not usable.

Senator **Evans**. What information do you have, and perhaps some of the others in the panel can inform us as well, it is my understanding that the planting of trees in a variety of areas, if done sufficiently and if allowed to grow, do end up changing the microclimates in the area.

It seems to me I read somewhere, oh, 10 or 15 years ago, about experiments conducted at the edge of the Sahara Desert, where the planting of sufficient trees had beneficial enough effect on climate to increase the moisture and help the trees continue to grow. I do not know what became of that experiment.

But to what degree can that happen? And how beneficial is that to stopping the desertification of certain areas, or increasing the potential for faster tree growth in other areas?

Mr. ROBERTSON. I think it is fairly well-established that trees can lower the temperature. In fact, one can feel it sometimes walking into a forest. Forests do have an effect on reducing the temperature.

Senator EVANS. Does that also, with a growing forest, have an effect in terms of added moisture in the air, or changes in climate so that close by the forest you maybe make the potential more benign for growth of other things, other trees or plants close by?

Mr. ROBERTSON. I will ask Dr. Sommers to comment on that.

Dr. SOMMERS. In terms of micro-climates, in terms of reforestation, and in the negative sense desertification, the establishment and maintenance of healthy forests help the climate both locally and regionally.

In places like the Sahel, social pressures have cut back the forest and have increased the desertification trend. If, in fact, forests can be established and maintained, the trend toward desertification would decline.

Certainly in any local area the establishment of a healthy forest regulates climate and other factors, too. The forest helps to clean the air and is a very beneficial presence.

Senator EVANS. Studying some of our recorded histories, we have examples of lands that once were productive and healthy and growing, and they are now pretty harsh.

Either careful study of the Bible or archeology of the Middle East suggests that indeed it was once a land of milk and honey, and that it is a lot harsher now than it once was.

From those of you who are involved in research on forests and growing things, do we know how this came about, the difference? Was it because trees which were once there were cut sufficiently to actually change the climates of those regions?

Dr. SOMMERS. It is probably a combination of effects. One is very large-scale deforestation in areas like Greece and throughout the Mediterranean, which had the effect of changing the micro-climate and the ability of the trees to grow.

There is some indication that regional precipitation patterns on that time scale have changed. We would be looking at regional precipitation patterns in some of these scenarios for climate change.

Senator EVANS. How much information do we have just looking at own our country and our experience?

Dale, in your page four, you talk about any significant change in climate will likely be associated with unstable highly-variable weather patterns that will require major revision and updating of that knowledge base. And climate changes will mean shifts in regional and seasonal precipitation patterns. We can expect changes in the structure and composition of our forests.

Do we have sufficient historical information in this country, or this continent, that tells us whether we have had periods of past climatic changes sufficient to actually change the nature of forests in certain areas of the country?

Dr. SOMMERS. On the geological time scale, we have very strong evidence, that have taken place since the last glaciation of changes.

Projections made by the modelers about climate changes indicate about a tenfold increase over what we have seen for forests during past climates.

Within our own normal stable climate regime, the variations that we have had in weather patterns have affected where forests have and where they have declined as drought has set in.

We have evidence, particularly for western pines, that tree species have extended their ranges when they have had a period of rainy warmer weather conditions. When trees have had drier, warmer conditions, they become less tolerant to disease, less tolerant to fire, and move back.

This is a very small variation compared to what the climate modelers are predicting will take place with global warming.

Senator **Evans**. Although it is smaller, can we relate—we know what the effects are. How confident are we in relating cause and effect?

When you say weather patterns shift or precipitation patterns shift, how well can we tell why those shifts have occurred in the past, that could change the nature of the forests?

Dr. **Sommers**. I would have to defer to the atmospheric scientists who have done the modeling on this regarding the nature of the change in weather patterns.

There is absolutely no question that, given a different climate than we have today, our forest ecosystems would be very different. Of particular concern to us and the types of projections that are being put forth now is the rapidity of the change.

If we could snap our fingers and have the climate of 100 or 150 years from now, all of the ecosystems would have readjusted, and there would be some winners and losers. But it would not all be that bad.

The ability of natural ecosystems, including forests, to adjust to the rapidity of the change is very, very worrisome. In fact, most of them would not be able to adjust without severe dislocation.

Senator **Evans**. And that all is based on the current modeling of global warming?

Dr. **Sommers**. That is correct.

Senator **Evans**. There is a lot of theory involved in that, is there not?

Dr. **Sommers**. Yes. There is a lot of theory. Irrefutable evidence of the increase of carbon dioxide in the atmosphere from observations is there.

The consensus from the atmospheric sciences is clearly moving toward a feeling of global warming.

The difficulty for us in ecosystem management is that temperature probably is not the most critical factor. It is the precipitation patterns. We are probably a few years away yet from accurate predictions of how those would vary, given different global warming scenarios.

Senator **Evans**. If next year was an extraordinarily cold spring and summer, and exceptionally rainy, that puts a different kind of point on the grid.

Dr. **Sommers**. Not necessarily. Moving from one type of climate regime to another one does not mean that change will occur in a straightforward manner. There will be variations both up and down.

I would say in terms of whether this summer was a "natural variation" or an effect of global warming probably will take about 10 years' hindsight to see how the record fills in.

But it does not necessarily mean that we will monotonically have increases in temperature and increases in dryness.

Senator **EVANS**. Some suggest only half facetiously that on the one hand we have global warming which, with all of its adverse consequences, and others suggest that nuclear warfare gives us nuclear winter.

That may be the way to keep balance is kind of a tiny nuclear war every once in a while to counteract global warming. [Laughter.]

I would not suggest that, Mr. Chairman. [Laughter.]

Thank you.

Senator **WALLOP**. Mr. Chairman, could I just make an observation along the line of questioning of Dr. Sommers? It is true, however, that the 10-year cycles provide some hindsight.

But 10 years ago in the winter of 1978 the National Science Foundation, which is not known for its glib forecasting, said that it was not entirely premature to forecast the next ice age within 100 years. And so I do not know what has happened within the decade, whether we are global warming or global cooling.

But I mean, in point of fact I think the first consequence is that Americans are loathe to have something going on that did not go on last year, and want an immediate answer.

But they did in fact predict the next ice age within 100 years just a decade ago, also due to the greenhouse effect.

Senator **WIRTH**. If I might ask you three quick questions.

Has the phenomenon this summer changed the directives that you sent down to various national forests for the development and implementation of forest plans?

Mr. **ROBERTSON**. No.

Senator **WIRTH**. Has your research on global warming or the potential future impact of global warming changed any directives on the forest plan?

Mr. **ROBERTSON**. I do not believe so.

Senator **WIRTH**. Should it?

Mr. **ROBERTSON**. Yes, it should, as soon as we get some evidence and research results we can work with.

Senator **WIRTH**. Following up on Senator Wallop's questions on fire management and the approaches that ought to be taken, should that impact on directives that you send to the forests on their forest plans, forest management approaches?

Mr. **ROBERTSON**. Yes.

Senator **WIRTH**. Has it?

Mr. **ROBERTSON**. We sent direction to the field on July 26th to put out all fires as quickly as we can.

Senator **WIRTH**. But in terms of next year, I mean assume that this year ultimately we will get over and the snows will come and everything will definitely be out.

What change have you started to develop? Or will there be changes of directives that come from you all out to the various forest supervisors?

Mr. ROBERTSON. Yes. As I mentioned, we will have a review of the fire policy, and we will have a revised fire policy in place before the next fire season. It will reflect the lessons that we have learned this year.

Senator WIRTH. Second, going——

Senator WALLOP. Would you yield? I have got to just cast out something.

I hope we do not have just a change in fire policy. I mean, it seems to me that this whole sort of management balance that is necessary, and that you might want to review not only the fire policy but the forest management timber harvest, the whole level, and try to move those all together at the same time.

Because if we go back to the era where a ranger was around to blow out your match for you, then you just go back to the fuel loading circumstance. So in line with your question, I am hoping we move both together.

Mr. ROBERTSON. It is obvious that one of the lessons we have learned, I believe, is that catastrophic fires are for real, and we have got to worry about dealing with this buildup of fuel in the forest. It is probably better to deal with it incrementally than all at once.

Senator WIRTH. The second point I wanted to make was it is very clear that while it is sort of easy for people to get up and point the finger at all fires, the fuel loading issue is a very real one.

And having fires and having a clearing out process is, as you point out in many cases, very, very helpful, and precisely the right policies that ought to be followed. And I just want to, for the record, make sure we understand that.

Now part of that question is the following. Of the four million acres that have burned, how many of those acres do you think were already heavily diseased or had problems of some other kind? Do you have any sense of that?

I mean, they were ready to burn, they were ready for change? It was not productive forest area? What transpired was healthy for the future of those forests?

Mr. ROBERTSON. For the bulk of the 1.6 million acres that burned in the Yellowstone area, it did not take an astute observer to fly over Yellowstone or hike through some of that country to see the dead lodgepole pine that the mountain pine beetle had killed several years ago. The beetle outbreak was still active.

We had an old dying lodgepole pine forest, and a lot of the Yellowstone area that burned over. So the question is, how do we convert that forest to a new forest over time?

In National Forest wilderness and under the National Park Service philosophy for national parks, there was no way to do that other than some kind of burn. We did not like to have burned the forest under the conditions it did. But, at some point, there had to be a regeneration of that forest.

Senator WALLOP. The key phrase is "over time," not overnight.

Mr. ROBERTSON. Or even over a month.

Senator WIRTH. Of the 1.6 million acres, what percentage of that was diseased heavily, suffering from drought?

Mr. ROBERTSON. Oh, I would——

Senator WIRTH. This is the 1.6 million acres in Yellowstone. What would you guess? A half, or two-thirds?

Mr. ROBERTSON. I would say over two-thirds of it.

Senator WIRTH. I am thinking as well of other areas, like you are familiar with the areas right along the front range in Colorado, where there has been tremendous suppression of fire for the last 60 or 75 years.

There has not been any of the clearing out process. There has been a great weakening of a lot of the forest. And the weakening of a lot of forest has brought on what some people believe is one of the causes for the infection of pine beetle, which brought along the killing of trees and the amount of dead forest there that is just waiting for a fire. And it increases every year.

I mean, we are going to anticipate that that is going to happen one way or another, that we are going to get a lot of fires in those areas where urban growth has moved right up next to the forest, where all-natural forest fire and clearing has been stopped.

Inevitably we are going to see more Yellowstone, more fires that are of great concern to people rather than less in the future, are we not?

Mr. ROBERTSON. Well, I just spent 2 days in Summit County, Colorado, and traveled around the County.

The forest type there is very similar to the kind we have in Yellowstone: mature lodgepole pine. The mountain pine beetle has hit Summit County very hard.

I think we are taking a different—I know we are, we are taking a different approach in Summit County. We have gone in and done some timber harvesting. We have harvested the mountain pine beetle-damaged lodgepole pine and even tried to move out in front of that outbreak to get some of the old stands that are very susceptible to mountain pine beetle.

I believe in a place like Summit County, Colorado, we can manage the fuel over time to try to avoid the kind of catastrophic event that we had in Yellowstone. We cannot afford a catastrophic event like the yellowstone fires in Summit County, because we have so much development and so many people.

We simply have to manage that fuel. There is a lot of below-cost timber sales going on in Summit County, Colorado. But we are managing that fuel incrementally over time, and I think we have a good chance of managing that situation to avoid a Yellowstone situation.

Senator WIRTH. Just as a final note, you have noted that the Forest Service wants to expand its current research program to include the effects of global warming on forests and rangeland.

What are the barriers that the Forest Service encounters in expanding this research program?

Mr. ROBERTSON. Well, as I mentioned, we have a sizable program in acid rain research. We have a cadre of about 75 scientists working on acid rain assessment, and this assessment work will be winding down.

So we badly need to shift this cadre of basically young scientists who are working on acid rain. It is a natural progression to get into atmospheric——

Senator WIRTH. It is just a shift, you do not need further resources? The existing resources are adequate?

Mr. ROBERTSON. Well, it would be a small program if we just depend upon existing resources.

Senator WIRTH. What should it be? If you were telling the Office of Management and Budget what ought to be, rather than what is, what would you like to have?

What would be the most productive figure for the Forest Service to have in terms of looking at long-term global warming and its impact on forests and rangeland?

Mr. ROBERTSON. Putting aside relative priorities and just speaking for the importance of this, we now spend $13 million in the acid rain program. As we phase that out, I think somewhere in the $20 million to $30 million category would be a logical program.

Senator WIRTH. So keep the $13 million, and you would like to have, say, $10 million or $12 million on top of that to do the kind of research job that should be done in terms of the examining and understanding and adapting ourselves as much as possible over the impacts of global warming?

Mr. ROBERTSON. Yes.

Senator WIRTH. Is there anything else the two of you might like to add? Excuse me, go ahead, Senator Murkowski.

Senator MURKOWSKI. Just a brief question. In your explanation of the Colorado effort to reduce the fire danger, do I understand you to say that you are putting up for sale some of the old growth pine, and the price you are getting is relatively low in relationship to newer growth pine, because it is old and diseased?

You are putting these sales up strictly to reduce the hazard from fire, as opposed to the objective of selling it for its value as old growth timbers? Is that generally correct?

Mr. ROBERTSON. That is basically right. Summit County has got a lot of lodgepole pine, like in Yellowstone Park. It is old, and it has had major infestations of mountain pine beetle.

So we have gone in and put up timber sales and sold infested stands, as well as move out into areas that are highly susceptible to mountain pine beetle, which we know are going to be attacked in the future.

Senator MURKOWSKI. Why were these not put for sale when they were more productive, prior to getting the infestation of the beetle, and so forth? Was it market conditions or were there some other reasons?

Mr. ROBERTSON. It was market conditions. It is a below-cost timber sale for us.

Senator MURKOWSKI. But now it is a management practice of the Forest Service to take areas, if there is a threat, from the standpoint of fire, and put these low-return sales up for sale, strictly to eliminate the hazard associated from leaving that stand in the sense of good forest management practice?

Mr. ROBERTSON. It all depends upon location. We have a lot of other places in Colorado where it would just be too expensive to go in and deal with the mountain pine beetle.

But Summit County, Colorado, is a high value area with a lot of development. We just would not be doing our job unless we went in and tried to manage this fuel loading over time. It is reasonably accessible country.

Senator MURKOWSKI. From the standpoint of forest management practice, is it better for regeneration after logging to do a slash-burn?

Or do you have greater regeneration after logging if you just go in with a reforestation program? Or is there any distinction? Or where are you from the standpoint of reforestation, if you have a forest fire? And compare the three for me.

Mr. ROBERTSON. I hate to be ambiguous here, but it depends upon the situation. It depends on the species present, for example.

Senator MURKOWSKI. Well, all things being equal, let us assume we are talking about the same species in the three examples.

Mr. ROBERTSON. Lodgepole pine needs fire.

Senator MURKOWSKI. You need a fire. OK.

Mr. ROBERTSON. Yes. To regenerate to lodgepole pine, naturally.

Senator MURKOWSKI. If you are going to log it, then you go back and burn after logging?

Mr. ROBERTSON. Yes. We have to open up those pine cones that stay good for 10 or 20 years.

Senator MURKOWSKI. So you would not log and not burn under normal conditions?

Mr. ROBERTSON. In general, yes.

Senator MURKOWSKI. And that is your objective, is regeneration?

Mr. ROBERTSON. That is right. Then on the old growth forests, for example, in the Pacific Northwest and in Alaska, we have so much non-commercial material. However, in Alaska we take most of that non-commerical wood out as pulp.

Because we have a lot of non-commercial logs, we either have to haul them out and do something with them, or burn them on site. Especially in western Oregon and Washington, we burn a lot of that wood right on site.

Senator MURKOWSKI. What do you do in Alaska where you cannot get it to burn?

Mr. ROBERTSON. We haul it out as pulp wood. That is why those pulp mills are so important to forestry in Alaska.

Senator MURKOWSKI. I do not want to get off the subject here, and I will not.

But finally, you get greater regeneration from a forest fire, and all things being equal, going into an area, as opposed to logging it and then burning the slash?

Mr. ROBERTSON. Yes; for lodgepole pine. But it depends when dealing with other species.

Senator MURKOWSKI. So clearly the whole process, from the standpoint of management and the capability to manage, can enhance regeneration that far surpasses what was in existence previously, from the standpoint of reducing carbon dioxide in the air through the forest process of photosynthesis?

Mr. ROBERTSON. Yes; in some areas, the logging is clean enough that we do not need to do burning. As a basic rule, we should not be burning if we can get the reforestation without the burning.

Senator EVANS. Mr. Chairman, just very briefly, and I know we have many other witnesses. But we seem to get mixed pictures, depending upon who you read and what you watch, about the fires of recent times in Yellowstone and elsewhere.

A friend of mine works for a television outlet in Salt Lake City and he said, for a month he was getting frantic calls from the networks saying, give us fire pictures, give us fire pictures. And if they were not dramatic enough, they would come back and want more.

Of course, I would guess that from looking at the evening news, the network news, most people in the eastern United States or urban areas of the United States would envision Yellowstone as totally in ashes, and the geysers coming up through the remnants of a forest that no longer exists.

An article in the Washington Post about a week ago suggested that an on-site view of those forests that had burned indicated that it was not a total burn. There were many green trees within the burned areas, that the green had already started back through the earth, and the cover was beginning to come back.

How accurately can you paint us a picture of just what those fires have done? What remains? What would somebody see if they went out there?

Mr. ROBERTSON. One would still see a lot of green in Yellowstone. First of all, only about half of the land area in Yellowstone is burned over.

Senator EVANS. I mean, within the burned area.

Mr. ROBERTSON. Within the burned areas, one can, still see a lot of green areas.

At the same time, one can see whole mountainsides that burned, where crown fires burned, the kind of damage one could see in the eastern press, and on TV.

Senator EVANS. That is all we saw.

Mr. ROBERTSON. Some fires really burned hot and wiped out everything in their pathways. The logs, the heavy fuel, the downtake trees, are a pile of ashes. The result is not just charcoaled tree stumps.

The burned area is really, a mosaic of some green that did not burn at all, and some part green, part brown that burned lightly. And then there are other mountain sites and areas where just everything is gone.

Senator EVANS. What is coming back? Even in the heavily-burned areas, has ground cover started back yet? What happens to the pine seeds within the cones? It took a fire to release many of those, did it not?

Mr. ROBERTSON. Yes; but they are not coming up yet.

Senator EVANS. Well, of course not.

Mr. ROBERTSON. But the lodgepole pine is a fire species. By that I mean the seeds within the cones are good for 10, 15 or 20 years. It takes heat to release those seeds. In most of those areas, I would expect a good crop of young lodgepole pine seedlings coming back in.

I have read about things already growing back. I was out there the weekend before last, and I did not see anything growing back yet. But there will be next spring.

Senator EVANS. There certainly will next spring.

Mr. **Robertson**. Yes.

Senator **Wallop**. I might just say there is still a drought on. One of the things that did not burn down were all the natural features. And there is plenty to see in Yellowstone that is still worthy of it having been the world's first national park.

Senator **Evans**. I would guess that the site of major forest fires themselves would be a fairly significant tourist attraction.

Senator **Wallop**. I do not think we need to attract them on the basis of a Mount St. Helen's kind of disaster. People will come there for part of the mosaic. Most of the big wildlife will have survived.

And certainly things like the Hagen Valley and Old Faithful, and the lake area, and all of those are absolutely worth going to visit. They have not disappeared.

Senator **Wirth**. Buy your tickets today.

Senator **Wallop**. We are giving them away now. We want people there.

Senator **Wirth**. Chief Robertson, we thank you very much. And to other witnesses, we thank you for your patience through all of this.

We wanted to make a record and do the best we can to further explain the balance of policy, so that the illusion of television has not created that the whole West has burned up or that the Forest Service has let everything burn.

I suppose we are all familiar with that illusion in this political season as well. And if we watch television one would be led to believe, I suppose, that George Bush was a major environmentalist, or Michael Dukakis spent a lot of time driving tanks. [Laughter.]

We thank you very much for being here. We will leave the record open for a couple of weeks for whatever further comments you think might be appropriate to make, or other questions that might come up from the outside or other members of the panel. Thank you both very much for joining us.

Mr. **Robertson**. Thank you, Mr. Chairman. As is evident, it is not always clear which way to proceed on some of these things. So we appreciate working with the Committee as we talk these things out and decide how we ought to proceed. Thanks.

Senator **Wirth**. Thank you all. Let us, if we might, proceed to the second part of today's hearings. And once again, let me thank you all for, the three of you, for your great patience.

Our witnesses on this next panel are Dr. Gregg Marland, Staff Scientist at Oak Ridge National Laboratory with the Department of Energy.

Dr. Marland recently authored a report for the Department of Energy on the potential of increasing the area or net growth rate of global forests to remove the world's CO_2 emissions, right on the point of our hearing today.

The second witness is Mr. Gary Moll, Vice President for Programs and Urban Forestry at the American Forestry Association. And I think a lot of comments, Mr. Moll, from the earlier witnesses I am sure that you are going to want to pick up on on behalf of the American Forestry Association.

Third, Dr. Dan Dudek of the Environmental Defense Fund, a senior economist here in Washington, will present to us his proposal for offsetting new emissions from stationary sources, power plants, for example, through reforestation and energy efficiency investment.

So gentlemen, thank you very much for being here, and again for being patient. I thought it was important with Chief Robertson that we make the record and all of that. So if you might proceed, again you are familiar with the rules of the Committee in which your testimony will be included in full in the record.

Ee would ask you to summarize your testimony in whatever way you think would be most beneficial for the Committee and for the record. And then we will get into your questions. Dr. Marland, why do you not start, and then we will go to Mr. Moll, then Dr. Dudek.

STATEMENT OF DR. GREGG MARLAND, STAFF SCIENTIST, ENVIRONMENTAL SCIENCES DIVISION, OAK RIDGE NATIONAL LABORATORY, DEPARTMENT OF ENERGY

Dr. **Marland**. Thank you, Mr. Chairman. It is a pleasure to be here and I enjoyed the opportunity to hear Mr. Robertson's remarks. It was very interesting to hear his discussion.

What I would like to do is to make some comments to make clear what is the magnitude of the effort we are talking about, if we are considering trying to offset some of the discharge from fossil fuel burning by taking the carbon up in woody matter.

I would like to make it clear at the outset that I think that review of forest policy and woody crops programs are entirely proper and very important responses to increasing carbon dioxide. This may not be totally obvious from some of the things I say that follow.

I would like to make clear, too, that Freeman Dyson and I, largely him, in 1977 and 1976 started this inquiry. And at that time we made it clear, I think, that we saw reforestation, with respect to carbon dioxide, as an interim measure, something that would be pursued in an emergency, that had limited capacity and that it was something that would be useful to buy time while we weaned the world energy system from fossil fuels.

But it had definitely a limited time span over which it was useful. I think my 1988 manuscript carries some of the same perspective. We envisioned woody crops as replacing energy feed stocks from fossil fuels. And then I think that forestry can play a longer-term role.

I would like to focus on U.S. data, although I think it is important to keep a global perspective. And I apologize, assumed I was going to be able to show some transparencies, but I think I can capture what is in them very quickly.

I have listed 15 countries. If we are going to reforest we have to ask where. If you list the 15 countries that have the largest land area, the 15 countries that have the most forests, the 15 that have the most people, the 15 that give off the most carbon dioxide from fossil fuel burning, you get a sense of where it all is.

If you do this, there are five countries that appear on all four lists, and these five countries are the Soviet Union, the United States, China, India and Mexico.

If you add Brazil, Canada, Indonesia and Japan, those nine countries make up over half of all those four categories, world land area, world closed forest, world population and world CO_2 emissions. I think a focus on those nine countries is where the forestry question has to begin.

If we get down to looking at a per capita basis, the United States is the largest emitter of carbon dioxide from fossil fuel emissions. The total U.S. emissions amount to 1,202 million metric tons (if metric tons are not a comfortable unit, there is not that much error made in just envisioning them as tons, but my comments will all be in metric tons) which amounts to a little over five tons of carbon per person.

I think a reasonable first question is as an individual, if I am responsible as an average U.S. citizen for 5 tons of carbon to the atmosphere, what do I have to envision in terms of forestry in order to take up my five tons of carbon.

If we use Forest Service numbers from the late 1970's and look at what the average net growth of U.S. commercial forests is, and then convert that to carbon, the average commercial forest in the U.S. that year was taking up roughly (0.8) of a ton of carbon per hectare.

You translate that across to my personal five tons of carbon, it is going to take me 15.7 acres to take up that carbon, at the average growth rate of U.S. commercial forest.

If we multiply that by the population, we end up with about 1,500 million hectares of land in order to offset our CO_2 emissions from the United States. If that were to take place, a good portion of that would have to be kelp, because that is 50 percent larger than the land area of the United States.

The conclusion is that the United States, with the highest per capita emissions of carbon dioxide, simply cannot take up, (offset) that carbon dioxide in forests with comparable growth rates to U.S. commercial forests.

The growth rate of trees is, of course, a function of many variables, site and stand characteristics. We could list species, structure, age, climate, water and nutrient availability and management practices.

The Forest Service has estimated that we could increase the net annual growth of commercial forests by two-thirds, simply by assuring that the forests were fully stocked. If we envisage intensive management practices we can do even better than that.

Let me cite the example of an American Sycamore plantation in Georgia, which was taking up carbon at 7.5 tons of carbon per hectare. This is nearly 10 times the average growth rate of commercial forests. But it has been done.

If we can get forests to take up carbon at 7.5 tons of carbon per hectare per year, then our personal contribution is only seven-tenths of a hectare. We could do this in less land area than current commercial forest in the United States.

Let me enlarge briefly to describe what this forest looked like, however. This was a plantation, the trees are planted on 4-foot centers, they are harvested every 4 years, and then sprout from stumps.

So if you would like to participate in this program on a half-acre residential lot, we are talking 1,361 sycamore trees. Every 4 years you harvest these trees. Of course, we are trying to save them from oxidizing to carbon dioxide, so you have got to put them in your garage while the next crop grows.

There are two basic defects in this concept related to taking up carbon dioxide, at least two. Again, we have to save these trees, or alternatively if we could use them to replace fossil fuels for burning, then we could keep this carbon dioxide cycling rather than having a continuous source from fossil fuel burning.

The other thing is if we manage forests for a maximum uptake of carbon, as emphasized by Mr. Robertson, we are talking about young vigorous forests. A mature forest has more standing stock of carbon, so there is an explicit tradeoff. If we are going to have maximum uptake of carbon, we are going to have less standing stock. You cannot store it and take it up at the same time, unless you are prepared to store that downed wood somewhere.

It has been estimated that a forest managed for maximum yield will have, on average, only one-third the standing stock of carbon as a mature forest. So that tradeoff exists.

Expanding on this idea of what the magnitude of the CO_2 problem really is in terms of forestry, if we take the total growing stock of all U.S. commercial forests, convert that to carbon, and divide by the annual CO_2 emissions from fossil fuel burning, we can find out that in order to put our CO_2 emissions into trees, we have to duplicate the entire standing stock of commercial forests in the United States every four and a quarter years. Our annual emissions are one-quarter, basically of the standing stock of commercial forests.

To bring the problem to an individual operational scale, we can pose the question with respect to a coal-burning electric power station.

To envision an electric power-generating station with 38 percent thermal efficiency, which is quite high by current standards, and 70 percent availability, it takes 191 hectares of these sycamores per megawatt of generating capacity.

Envision a 1,000-megawatt plant. We are talking about a forest of American sycamores around that plant to a radius of a little over 15 miles. Again, this is fast-growing, highly-managed sycamore trees that are harvested every 4 years, and you either burn the sycamore trees or store the wood so it does not oxidize.

The point I am making using data for American sycamore in Georgia is that net annual growth of forests can be much higher than at present if we are talking about fast-growing species, advanced management techniques and high quality sites.

We are talking about species selection, genetic screening, spacing, thinning, pruning, weed control, fire and pest control, fertilization, irrigation—however far one can envision going.

One of the other figures that I had hoped to present gives some numbers for maximum mean annual yield for a couple of forests which have been intensively managed and it shows how different management practices have increased the yield.

For Douglas fir in Washington, which I will read, for example, the natural stand takes up carbon at 2.8 tons of carbon per hectare per year.

With careful plantation establishment, this can be increased to 3.6. By adding nitrogen fertilizer it can be increased to 4.4. With some genetic control, it can be increased to 4.9. The targets for the scientists who are working on this was 12.5.

But again, this is intensive management which does not come cheaply. The maximum that has been achieved for these growth rates is 15 tons of carbon per hectare per year, but this was a tropical eucalyptus.

The maximum that has been achieved in the United States was for hybrid cottonwoods, grown by Heilman and Stettler in Washington. They were raised in short rotation in fertilized, irrigated plots in western Washington. And they took up nearly 15 tons of carbon per hectare per year. That is total production.

Other energy wood crop studies in the United States commonly report yields in the range of 5 to 10 tons per hectare per year on a variety of sites. Also over the long term I think we can envision tree improvements will take place through selection and cloning. We can envision improvements in growth rate, drought tolerance, nutrient use efficiency, all things that yield long-term increases in carbon storage.

There are a couple of factors which obviously need to be considered, if we are going to envision long-term storage of carbon in trees, that I have not discussed here. One, of course, is that these intensively managed forests are going to require energy to make the system go, and that is not included.

Also, as has been mentioned earlier, acid deposition and photochemical oxidants are likely to have deleterious effects on growth rates. And we do not really have an idea what increasing CO_2 is going to do. How will the climate change, what effect will it have on forestry, and will the CO_2 itself, as it increases in the atmosphere, have some impact on the forests

To conclude, I would simply reiterate that the magnitude of current CO_2 emissions is immense. Any program that will offset or significantly affect net emissions will likewise be immense in both scale and cost. Yet it is physically possible to have a significant short-term effect through forest policy.

If climatic changes are to be as dramatic as many believe, we have to ask what are the other choices? On the other hand, if the question is whether we can continue, over the long term, to burn fossil fuels and at the same time avoid increasing atmospheric CO_2, the answer with respect to forest policy is "no."

[The prepared statement of Dr. Marland follows:]

THE ROLE OF U.S. FORESTRY IN ADDRESSING THE CO_2 GREENHOUSE PROBLEM

REMARKS BEFORE THE SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

by
Gregg Marland
Environmental Sciences Division
Oak Ridge National Laboratory

September 19, 1988

We are confronted with the possibility that it may become necessary to limit the increase in atmospheric CO_2 in order to avert adverse changes in the global climate. One approach would be to stimulate the growth of forests to take up in woody matter enough carbon to offset the discharge of CO_2 from fossil fuel burning.

Let me say at the outset, lest it be lost in my remarks that follow, that I believe serious examination of forest policy and woody crops programs is an entirely proper and important response to increasing atmospheric carbon dioxide. Forestry should probably play, at some level, a role in our action. Let me say, too, that when Freeman Dyson and I first wrote on this subject in the late 1970's, we tried to make it clear that we saw carbon uptake by trees as an interim measure that had limited capacity and would be useful primarily to buy time while our energy system was weaned from fossil fuels - a short term emergency measure. We envisioned that it would take decades to convert from fossil fuels to some other energy system and that reforestation could restrain or decrease atmospheric CO_2 levels during that interval. My 1988 manuscript contains the same perspective. Solar or biomass fuels could fill a longer-term role if woody crops can replace fossil fuels as energy feedstocks.

That having been said, what I would like to do here is to make clear the magnitude of what we are talking about and to raise some points that need to be seriously considered. If a program is implemented in the name of CO_2 we want to be sure it is meaningful and not merely symbolic.

I will focus on U.S. data although it is useful to keep a global perspective. As shown in figure 1, the U.S. is still the largest single source of CO_2 to the atmosphere from fossil fuel burning (including a small contribution from cement manufacture) with 1202 million metric tons (1 metric ton = 2205 pounds) of carbon emitted in 1986. This comes to just over 5 tons of carbon per person. An interesting first question is how much forest it would require to take up this personal share of CO_2. If we take the average net annual growth of U.S. commercial forests, which was estimated at 3.15 cubic meters per hectare per year in 1977 (fig.2) (a hectare is about 2 1/2 acres) and translate this to roughly 0.8 tons of carbon per hectare per year, we see that it would require 6.35 hectares (15.68 acres) per person to take up our individual CO_2 contribution. Multiplied by 237 million people this becomes 1,504 million hectares- which is some 50% larger than the land area of the U.S. Conclusion, the U.S., which has the world's highest per capita CO_2 emissions, cannot take up all of its own CO_2 in forests with growth rates comparable to existing commercial forests.

The growth rate of trees is, of course, a function of site and stand attributes (species, structure, age, climate, water and nutrient availability, silviculture practices, etc.). As seen in figure 2, the U.S. Forest Service estimated in 1982 that the average net annual growth of commercial forests could be increased by almost 2/3 simply by assuring that they were fully stocked. Intensively managed forests can do even better. To illustrate, consider an intensively managed forest of American sycamores. Steinbeck and Brown have grown American sycamores on 4-year rotation in Georgia with a carbon uptake of 7.5 tons of carbon per hectare per year. At this growth rate, the per capita forest requirement would be reduced to only 0.67 hectares and 158 million hectares would offset the full U.S. CO_2 emissions. This is less than the current area of U.S. commercial forest. The conclusion is that if simply enlarging the area of forest can't achieve a full offset, intensively managed forests could.

Two defects in this concept are related to the fact that this particular experiment was based on a rotation schedule whereby trees were harvested every 4 years to maintain the high growth rates of young vigorous plants. First, if these trees are harvested, net carbon emissions are not reduced unless the trees are either protected from oxidizing to carbon dioxide or are used to replace fossil fuel burning. Second, according to Cooper, when forests are managed for maximum sustained yield, the average standing biomass (i.e. carbon storage) is approximately 1/3 that of mature forests. In other words, there is an explicit trade-off between maximum carbon storage and maximum rate of carbon uptake.

Before returning to a discussion of reforestation and potential growth rates, let me further illustrate the magnitude of the CO_2 problem with respect to forestry. According to figure 2, the total growing stock of U.S. commercial forests is around 20,120 million cubic meters of wood with a carbon content of roughly 5030 million tons. To offset, as wood, 1202 million tons of fossil fuel emissions per year, we would have to duplicate that forest mass every 4.2 years. Also note that, as devastating as the Yellowstone Fire has been, if we estimate that it burned perhaps 56 tons of fuel per hectare (25 short tons per acre), the CO_2 emitted from 1 1/2 million acres is only 2.8 percent of the annual U.S. emissions from fossil fuels.

To bring the problem back to a scale we can deal with, it is illuminating to inquire how much forest would be required to offset a particular fossil fuel burning activity. Consider a coal-fired electric power station. If we assume 38% thermal efficiency and 70% availability, it would require 191 hectares of American sycamores per megawatt of generating capacity to offset the CO_2 emissions. For a 1000 MW plant that means the power plant would be surrounded by plantation to a radius of 24.7 km (15.3 miles) - sycamore trees planted at a 4 foot spacing and harvested every 4 years. I have not considered the energy required to operate such as intensively managed forest but a reasonable estimate is that the energy required is about 12% of the energy produced.

The point I make in using data for American sycamore in Georgia is that net annual growth of forests can be very much higher than at present if fast-growing species are grown with advanced silviculture techniques on optimum sites. Silviculture practices can include species selection, genetic screening, spacing, thinning, pruning, weed control, fire and pest control, fertilization, irrigation, harvest cycle time control, site preparation, etc. Two examples illustrate what management can do (fig. 3). Figure 4 gives further data on growth rates of stemwood and shows measured values up to 60 cubic meters per hectare per year (15 tons C per hectare per year). Heilman and Stettler have reported hybrid cottonwoods in short rotation on fertilized, irrigated plots in Western Washington achieving nearly 14 tons of carbon per hectare per year of total production. Other wood energy crop studies in the U.S. are reporting carbon uptake of 5 to 10 tons per hectare per year on a variety of sites.

Tree improvements through selection and cloning can be expected in areas such as growth rate, drought tolerance, nutrient use efficiency, and pest resistance. One of the current concerns over the loss of forests is to ensure the preservation of sufficient genetic diversity so that we can have options for pursuit of new goals, adaptation to changes in site or climate, and for survival within the community of pests, pathogens, and competitors.

Let me add a list of a few of the things that have not been considered here but need to be part of the discussion: the dollar and energy costs of intensive forest management, the negative effects of acid deposition and photochemical oxidants, the effect on tree growth rates of increasing ambient CO_2, and the effect that CO_2-induced changes in climate will have on forests. All of these will affect what we can, or are willing, to do with our forests.

To conclude I would simply reiterate that the magnitude of current CO_2 emissions is immense and any program that will offset or significantly affect net emissions will likewise be immense in both scale and cost. Yet it is physically possible to have a significant short term effect through forest policy. And, if climate changes are to be as dramatic as many believe, we must ask what the other choices are for either dealing with atmospheric CO_2 or coping with the attendant changes in climate.

On the other hand, if the question is whether we can continue, over the long term, to burn fossil fuels and at the same time avoid increasing atmospheric CO_2, the realistic answer with respect to forestry related solutions is "no".

Acknowledgement

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Figure 1

AN 11-COUNTRY SAMPLE TO FOCUS THE CO_2 PROBLEM

		Land Area (10^6 ha)	Closed Forest (10^6 ha)	1985 Population (10^6)	1986 CO_2 Emissions (10^6 tons C)	fossil fuel/ area of CO_2 emissions/ closed forest (tons Cyr^{-1}/ha forest)	per capita emissions (tons C/person)
1.	U.S.S.R	2227	792	278	1011	1.3	3.6
2.	U.S.A	913	195	237	1202	6.2	5.0
3.	China	933	125	1063	554	4.4	0.53
4.	India	297	73	761	144	2.0	0.18
5.	Mexico	192	48	79	74	1.5	0.91
	Sum (1-5)	4562	1233	2418	2985		
	% of Total	34.89	41.98	49.94	54.16		
6.	Brazil	846	396	135	53	0.1	0.38
7.	Canada	922	264	26	105	0.4	4.1
8.	Indonesia	181	123	165	28	0.2	0.17
9.	Japan	37	24	120	256	10.7	2.1
	Sum (1-9)	6548	2040	2864	3427		
	% of Total	50.07	69.46	59.15	62.18		
10.	Zaire	227	106	33	1	0.01	0.03
11.	W. Germany	24	7	61	186	26.6	3.1
	Sum (1-11)	6800	2153	2958	3614	1.7	1.2
	% of Total	52.0	73.3	61.1	65.6		

Area and population data from World Resources Institute, 1986.

Figure 2

DATA ON COMMERCIAL FOREST LAND IN THE UNITED STATES, 1977
(Data from U.S. Forest Service, 1982)

		U.S. Total
Area	Total Land Area (10^6 ha)	912.9
	Total Forest Area (10^6 ha)	298.2
	Commercial Forest Area (10^6 ha)	195.3
Productivity Class (By Area)	>8.4 m^3/ha yr (10^6 ha)	19.2
	5.95 - 8.4 m^3 ha^{-1} yr^{-1} (10^6 ha)	40.0
	3.5 - 5.95 m^3 ha^{-1} yr^{-1} (10^6 ha)	81.0
	1.4 - 3.5 m^3 ha^{-1} yr^{-1} (10^6 ha)	55.1
	Average net Annual Growth (m^3 ha^{-1} yr^{-1})	3.15
	Potential net Annual Growth (m^3 ha^{-1} yr^{-1})	5.18
Ownership of Commercial Forest	Federal (10^6 ha)	40.2
	State, Local, Indian (10^6 ha)	14.7
	Forest Industry (10^6 ha)	27.9
	Other Private (10^6 ha)	112.5

Figure 3

PRODUCTIVITY INCREASES ATTRIBUTABLE TO INTENSIVE PLANTATION MANAGEMENT

Case	Maximum Mean Annual Yield (Tons Carbon ha^{-1} yr^{-1})
Douglas Fir in Washington	
Natural stands	2.8
Silvicultural treatments	
Plantation establishment	3.6
Nitrogen fertilization	4.4
First-generation genetics	4.9
Target	12.5
Loblolly Pine in North Carolina Pocosins	
Natural stands	1.8
Silvicultural treatments	
Drain and plant	3.5
Bedding	4.3
Preplant phosphorus	5.3
Nitrogen fertilization	5.9
First- and second-generation genetics	7.2
Target	15.0

BASED ON FARNUM ET AL. (1983)

Figure 4

GROWTH RATES OF STEMWOOD IN SOME MANAGED FORESTS AND PLANTATIONS

Forest Region or Type	Stemwood[1] (tons C ha^{-1} yr^{-1})	Rotation (yr)
UK average (conifer Plantations)	2.5-	40-65
New Zealand and Australia (radiata pine)	4.5-8.8	20-50
Sub-tropical eucalyptus	1.3-7.5	8-25
Tropical high forest (managed)	0.1-1.8	
SE Asia dipterocarp forest (managed)	1.1-4.3	70-100
Malaysian dipterocarp plantations	1.1-2.3	18-45
Tropical pines	3.8-11.3	8-30
Tropical hardwood plantations	6.3-8.8	8-20
Tropical eucalyptus	4.5-15.0	7-20

BASED ON NAMBIAR [1984]

Senator WIRTH. Dr. Marland, thank you very much. Mr. Moll?

STATEMENT OF GARY MOLL, VICE PRESIDENT, PROGRAMS, AMERICAN FORESTRY ASSOCIATION

Mr. MOLL. First, I want to commend the sponsors of the National Energy Policy Act, and say that we consider it to be one of the most important environmental pieces of legislation over the last decade or so, and that our association would strongly support that bill.

We would also like to suggest that within that legislation that there be a consideration for adding an element of putting trees in, for helping to improve our energy possibilities for the future. I would like to talk a little bit about those in a couple of ways here.

First, I would like you to consider a communities grant program to towns and cities to encourage them to initiate conservation programs within their urban forestry efforts.

Senator WIRTH. Mr. Moll, let me just ask you, who do you all represent? And let me make sure that I understand. You say this is an important piece of legislation. I always like to know——

Mr. MOLL. Just who said that.

Senator WIRTH. Yes. I want to quote you essentially, but I want to know who I am quoting. [Laughter.]

Mr. MOLL. I represent the American Forestry Association. I am Vice President of Programs, as you said. And the testimony that I am presenting is the American Forestry Association.

Senator WIRTH. Who is the American Forestry Association?

Mr. MOLL. It is a national citizens' conservation group. It is the oldest citizens' conservation group in the country, 113 years old.

Also, within this organization is a group called the National Urban Forest Council, which is a coalition of citizen and community leaders that are active in working with the management of urban forests in towns and cities.

Senator WIRTH. Are you representing the forest product companies? Any of the big timber companies?

Mr. MOLL. We do have some members, but mostly we are citizen-based, we are individual citizens belonging to a private association with really——

Senator WIRTH. You are really a citizen conservation group and not an industry group?

Mr. MOLL. Yes; very definitely. With that, then, we would like to throw our support toward this bill and talk about some of the possibilities that we feel are there for forests.

Not just in capturing CO_2 for the global warming purposes, but also in what they might do for saving energy on the ground in towns and cities, the other side of the equation, what we are putting out in the realm of CO_2.

First off, I would like to look at the problem that is going on in our cities right now. A study we did last year showed that there are about four trees dying for every one tree that is planted within our cities.

It has shown us that the quality of these forests we have, those trees that give us the cooling, that have created those communities that we live in, that our forefathers gave us, that that is declining, those areas are getting warmer.

From some research that has gone on at the Berkeley Laboratory, we see also that because those trees are dying the urban heat island effect has increased, increased temperatures of 3 to 10 degrees in many areas.

That increase has made it uncomfortable in our cities, and has caused us to turn on our air conditioning and put CO_2 out into the air.

So one thing we would like to propose is some part in this bill that would encourage towns and cities and individuals to plant and grow more healthy trees within their cities to give us the shading that we need to offer the cooling, and prevent us from putting the CO_2 out into the air.

We think that that can really be significant. The research shows that just three trees around a building or around homes can reduce the energy used by 10 to 50 percent, depending on where your particular city is located.

If you are down in Arizona or somewhere you may be increasing it 50 percent. If you are up in the far Northeast it may be less.

Secondly, that there are about 100 million planting places within the cities that do this shading. They are strategically located planting spots. And we would like to find some way to encourage planting in those areas.

Doing that planting it seems, according to the study and the research, would save about a half a quad of energy a year, and 18 million tons of CO_2 emissions.

We personally are—AFA as a citizens' conservation group is dedicated to an educational program that will use our resources as best we can to make people aware of this problem and do some of the things that are important. But we do not feel that that is enough by any means.

We feel there also needs to be some economic incentives to the civic leaders, to community leaders, to government officials.

They need to know that, number one, that they are part of a national effort, and two, that the Federal Government is willing to help in some ways in getting things going in their communities.

When they know those things, we believe they will act. Our group, that National Urban Forest Council, has found that it is not hard to get these citizen groups and communities to do something one at a time, but to try to get a national effort going all at once, that is a lot bigger problem. That is where we would really like to see the help and think this bill could address that problem.

We are not so naive to think that planting alone or growing trees or increasing productivity on some of the trees is going to stop the global warming problem in its entirety. But it will help.

It will surely help, and we think it is a powerful political idea, because it empowers people through community action to address a very large problem, a global problem. It gives us something very straightforward that we can do, and gets us thinking along the right lines.

So with that, I would like you please to consider, from our association, the American Forestry Association, adding a community forestry element to S. 2667.

Then before I close my testimony, if I could add just three other areas where I think some other improvements could be made.

First off, as we have heard some discussion on the estimates for growth on private and public forest lands, we think there is a major opportunity to increase the productivity of forests. And that is a direction we ought to try to promote.

Our figures show that in general that there is an economic opportunity, that economic opportunity being something that can return a 4 percent economic increase, if you thin a stand of trees for example.

There is that opportunity for about 17—I do not know the total number of acres, but there is an opportunity to increase the productivity 17 million cubic feet by just taking advantage of those particular areas. Those are generally using the Forest Service figures that Chief Robertson talked about.

Also, through that process then we will increase the CO_2 consumption by the trees. I think that is a very positive element, and that that increase in productivity could handle, or balance out about one-third of the total CO_2 that we now produce.

Again the United States being—I talked about towns and cities. I mean, we are producing about 25 percent of the total CO_2. So we are the very big culprits, as has been pointed out. We ought to look at ourselves first and do something about that at home, as well as in our forests.

The second element of that came into the discussion earlier, that when we do talk about increasing productivity, and that we are in a global warming situation, we are making it very difficult to grow trees for many people that are growing them on 30- to 100-year rotation.

So there really does need to be a lot of research to figure out how we are going to grow those trees, maybe where we ought to grow different species of trees, how we have to change our management techniques.

Finally, the, the last point that I guess we would like to make is that we are appalled by what is happening in tropical forests, the slash and burn policies, to convert land to long-term agriculture in very large areas.

Those huge areas that we see going on now is adding a great deal to the CO_2 levels within this greenhouse that we all are living in. And so we really do applaud any legislation that would help stop our policies from supporting that kind of activity.

Even though it is not in the United States any activities that we can do to stop supporting those sort of activities, then we would support. We would like to be able to say soon that the United States does not contribute to that problem in any way.

So in conclusion, what I am basically saying is that the global warming symptoms in the environment are symptoms that our environment is indeed out of balance, and that the causes of this out-of-balance situation is human activities.

We are starting now to understand why we are putting the greenhouse gases into the air, and if we act wisely, from many fronts, not just one, certainly not just growing of trees but many other fronts, this being one of them, that we can indeed change this direction.

As far as forests, though, we think that the global warming situation offers one of the most compelling arguments since the rape of the forests 100 years ago, when Teddy Roosevelt and Gifford Pinchot got into the conservation movement. We think this particular situation offers one of the most compelling reasons to get back into conservation, to do the job we need to do with trees, both in the rural areas and in those cities, that 70 million acres of towns and cities across the country that are really producing CO_2.

[The prepared statement of Mr. Moll follows:]

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Statement of

Gary Moll
Vice President, Programs
American Forestry Association

to the
Senate Committee on Energy and Natural Resources

September 19, 1988

Mr. Chairman. Members of the Committee.

I am Gary Moll, Vice President for Programs for the American Forestry Association and Chairman of the National Urban Forest Council. The American Forestry Association is the nation's oldest citizen's conservation organization, with a national membership dedicated to the improvement of America's trees and forests. The National Urban Forest Council is a coalition of professional and citizen leaders across America who work with states and communities in managing and improving the 70-million-acre forest where most of us live and work.

I commend the sponsors of S. 2776, the National Energy Policy Act. It is perhaps the most important piece of environmental legislation to be considered in many years, and you can be assured of the active and enthusiastic support of our organization as the Congress considers it.

My purpose today, however, is to ask the Committee to consider adding an element to S. 2776 that we feel would strengthen and improve it. That element would consist of a title creating a new community grant program to cities and towns -- an incentive to help encourage and support aggressive new energy conservation elements to their urban forestry programs.

The evidence pointing toward the need for such a title is fairly straight-forward. Our urban forests are dying. A 1987 survey done by the American Forestry Association indicated that, on average, 4 trees are dying or being removed for every new one planted today. The shady, pleasant communities created by our forefathers are becoming, instead, urban "heat islands" where average temperatures 3 to 10 degrees higher than the surrounding countryside are common.

Research has shown that breaking that "heat island" effect can be one way to reduce energy consumption -- particularly peak-load energy consumption associated with air conditioning during peak periods. Studies at the Lawrence Berkeley Laboratory of the University of California at Berkeley, and reported just last month at the American Council for Energy Efficient Economy (ACEEE) Summer Study on Energy Efficiency in Buildings demonstrate that the most cost-effective way to attack the urban heat problem is to improve the density and health of the urban forest.

Their research shows, Mr. Chairman, that just 3 trees around the south and west sides of a

The National Citizens Organization For Trees, Forests, and Forestry

house can reduce air conditioning bills by 10 to 50 percent, depending on the conditions in the community. We estimate that, in total, there are somewhere on the order of 100 million available "tree spaces" in urban communities where new trees are urgently needed. Planting those trees could result in a savings of one-half quad of energy, and as much as 18 million tons of carbon dioxide production, each year.

Our work with the National Urban Forest Council convinces us that mobilizing American citizens to improve their community's environment is a relatively easy task, when you work one community at a time. What's difficult is to mount a massive national effort. We at AFA are committed to carrying out the most effective national public education campaign on this issue that our resources will allow. We think that will help. But it won't be enough.

In addition, there needs to be some economic incentives, to help capture the attention of civic leaders and local government officials. If they are convinced that their local efforts are part of a national battle to reduce carbon dioxide emissions, and if they are shown that the federal government is willing to help them in that effort, they will act.

Mr. Chairman, we are not so naive as to think that planting urban trees is going to solve the carbon dioxide problem, or turn the global warming trend around. We do think, however, that this program offers one very attractive step in the right direction. It is attractive for several reasons. It is relatively low-cost, and very cost-effective. It can be started instantly -- today, if we wish. The technology is at hand.

This idea is politically powerful, because it empowers people and calls them to individual and community action on a critical global issue. It helps demonstrate that the fight for a better environment is everybody's fight, and that it can start with each of us, in our daily lives, where we live and work. People who view the global warming issue in that light, and who have done their part to heal the environment, are going to expect similar performance from their business and political leaders.

We urge you to consider adding an community forestry incentives program in S. 2776 for these reasons, and stand ready to assist in any way possible in its drafting and passage.

Before I conclude, Mr. Chairman, I would like to briefly touch three other aspects of the very close connection between forestry and the greenhouse effect.

Forest Service data shows that public and private forestlands in this country have a tremendous potential for improved tree growth. They estimate that forest owners have economically feasible opportunities (meaning those that will return a 4 percent annual return on investment) that could increase annual forest growth by up to 17 million cubic feet per year. If those investments were made, the carbon dioxide trapped and stored in that additional wood growth would add up to about one-third of what we now produce from the burning of fossil fuels in this country. In other words, improved forest management could significantly accelerate the biological "downdraft" that removes carbon dioxide from the atmosphere. Clearly, there would be other environmental and economic benefits as well.

But forest management -- and, particularly, increasing forest growth rates -- is not going to be made easier if climate changes are too rapid or moisture regimes change too much. Forest managers must make investments of 30 to 100 years, betting on growing conditions that are somewhat similar to those of the past. That may no longer be a good bet. If it isn't, and they face significant departures from historical conditions, then they need more information, and they need it fast. If they are faced with planting different species on some sites, or perhaps with abandoning other sites, because of climatic change, the people making today's decisions need to know those facts as soon as possible.

All of this argues for an accelerated research program, both in terms of understanding and quantifying the global warming trend, and in determining its impact on trees and the way we manage them. We will make that argument more directly when it comes time to testify on the Forest Service's research budget, but we wanted to make sure it was recognized in connection with the bill before you today.

Finally, a word about tropical deforestation. Our Association is appalled at what is happening to tropical forests, and the November-December issue of our magazine, American Forests, will be devoted almost entirely to that situation, and to its connection with international climate, wildlife, species preservation, and economic issues.

We are particularly repelled by the projects that slash and burn tropical forests in an attempt to convert those lands to long-term agriculture. The impact of those huge conversions is clearly a significant factor in today's carbon dioxide imbalance, largely because the wood is burned and what little organic matter remains in the soil is subject to almost-immediate oxidation. We applaud the fact that S. 2776 would bring additional federal policy attention to that situation, and we hope that the combined efforts of several such policy initiatives will assure that, in the very near future, we will be able to say with confidence that the United States is no longer underwriting any such project and is, instead, providing assistance to those nations to help them meet their very real needs for economic growth while, at the same time, reforesting those areas that cannot come back effectively from their current condition. Its a large challenge, but one that needs to be faced.

Mr. Chairman, what I have tried to say today is that global warming is a symptom of an environment out of balance -- largely because of human activities. Now that we understand -- and are faced with the graphic evidence -- of the tremendous damages this imbalance can inflict on people everywhere -- this Nation must act. If we are to act wisely, and exert the international leadership required, we must act together -- on many fronts at once, and with as many of our citizens joining into the action as possible.

We are convinced that the global warming threat brings the most visceral, compelling, moving argument for forestry action -- both urban and rural -- both public and private -- since the massive rape of forests in the last century led to the pioneering conservation thrust of the Teddy Roosevelt - Gifford Pinchot era.

We don't believe -- and wouldn't propose -- that better forests will solve the global warming crisis. But we do believe -- very strongly -- that the improvement of trees and forests is one essential element in the all-out campaign that we must mount to right the environmental wrongs of the past and begin to heal the earth.

We appreciate the chance to express our views, and would be happy to answer questions, or to provide assistance in any way the Committee would desire.

Senator **Wirth**. Mr. Moll, thank you very much. Dr. Dudek.

STATEMENT OF DR. DANIEL J. DUDEK, SENIOR ECONOMIST, ENVIRONMENTAL DEFENSE FUND

Dr. **Dudek**. Thank you, Mr. Chairman, and Members of the Committee. I would like to thank you for the opportunity to discuss the offsetting of new CO_2 emissions as one means of beginning the slowing of greenhouse gas emissions accumulation in the atmosphere.

While this policy is completely general and not tied to any specific method of compensating for new CO_2 emissions, one option involving the planting of trees appears to be particularly attractive.

My testimony will center on the assumption and its complementarity with the Conservation Reserve Program of the Food Security Act of 1985.

Testimony today has touched on the three main aspects of interaction of forests with the atmosphere. First, forests as sources of CO_2.

We have mentioned the burning of some 4 million acres in the United States this year, an area roughly twice the size of the State of Connecticut. Globally, we lose roughly an area the size of the State of Indiana each year to deforestation.

Forests also are victims under a changed climate. It has been mentioned that the mid-latitude forests of the world right now contain approximately the same amount of carbon as that in the atmosphere.

Estimates of high rates of change for climate indicate that forests' reproductive failure would cause a significant reduction in area, large releases of CO_2 to the atmosphere, and a loss of that carbon fixation possibility.

Also, we have heard addressed the question of forests as solution. As Dr. Marland had indicated, sequestering about 5 gigatons of carbon per year in terms of annual additions would require something between 1.3 billion and 1.6 billion acres of new forests a year. By comparison, the total land area of the United States is about 2.3 billion acres.

However, a more modest proposal in attempting to compensate for all CO_2 emissions is to begin the first task of breaking the rapid growth of greenhouse gas emissions in the atmosphere.

For some gases, like chlorofluorocarbons, we expect that this will occur in January of this year as the Montreal Protocol takes effect.

One way to slow emissions growth while allowing growth in energy production is to require all new CO_2 sources to offset their emissions. That is, new CO_2 sources would have to find compensating CO_2 emission reductions elsewhere.

These could be generated in a variety of ways. Investments in energy conservation would reduce energy demand. Mr. Moll gave an example of urban tree-planting, for example, would reduce fossil fuel burning and reduce emissions.

Investments could also be made in mass transit options. Also the scrubbing of CO_2 in post-combustion treatment has also been studied.

However, another possibility is offered by a forestation, particularly if coupled with the Conservation Reserve Program.

Briefly, the Conservation Reserve Program is intended to remove highly erodable agricultural land from production. Private landowners offer to convert this land to permanent cover in exchange for an annual government payment. Contract run is typically 10 years. The government additionally subsidizes up to 50 percent of the cost of establishing the cover practice.

The legislation has, and program has as an objective the retirement of between 40 and 45 million acres of crop land. This is approximately 10 percent of the nation's crop land base.

In creating the program Congress also set a goal, that 5 million acres of this land should be forest. To date, however, less than one-third of that goal has been achieved. Many analysts attribute this low rate of sign-up and voluntary conversion to the fairly low government payments, averaging roughly $50 an acre.

In assessing the feasibility of planting trees for compensating for new CO_2 emissions, I used the planned increases in fossil fuel electric-generating capacity for the years 1987 to 1996. This is some 25,000 megawatts proposed in 20 different states.

The conclusion is that roughly 10 million acres of new trees could offset this decades' worth of new fossil fuel power plants.

In terms of costs, right now the USDA is spending about $1.1 billion per year in rental payments alone. Cost-sharing establishment practices has been an additional $1 billion. This is for the roughly 25 million acres that have been signed up so far. Remember, only 1.6 million has in fact been converted to forest use.

Over the life of the existing Conservation Reserve Program, this is about $6.8 billion in present value terms. If we adopted an offset program, and all of that offset were using the Conservation Reserve Program option, this would without government cost-share payments would result in about a 7 percent increase in the capital costs of constructing new electric-generating facilities.

The present value would be about $9.2 billion over a 50-year horizon. With conservation payments, however, continuing, it would drop to about 5 percent of capital costs, and a total program cost over a 50-year life of about $4.6 billion.

A middle-ground policy of providing some payments to conservation-targeted acreage would provide an incentive to use those lands for offsets. Justification, of course, is the conservation benefits that you would additionally accrue.

In any of these calculations, no account has been taken of any revenues that would be generated from subsequent harvests.

Clearly, cost varies by tree species. The estimates used have been from existing research on species, mainly in the eastern growing conditions. Other species clearly need to be researched.

In addition, the policy has been evaluated for application on a state-by-state basis. Certainly, if there are substantial benefits associated other than with such a policy, other than for mitigation of reduction of the greenhouse gas accumulations, states may prefer to see those investments made within states.

In examining the feasibility of the application of those in-state investments, in aggregate we find that less than a quarter of the targeted acreage in these states has been enrolled.

Since only a quarter of the current Conservation Reserve Program acreage goals would have to be forested to achieve the aims of this policy, in the aggregate there is more than enough acreage available.

In the details, though, some individual states, such as Utah and Nevada and Arizona, would suffer both from the lack of qualifying erodable lands, as well as relatively poor conditions for reforestation.

In summary, by piggybacking an offset policy upon the Conservation Reserve Program, we would receive benefits to agriculture in the form of reducing excessing wind and water erosion, reducing the production of surplus commodities, and providing financial benefits for farmers.

The environment would benefit from reduced resource degradation, from reduced quantities of sediments, pesticides and nutrients that have been critical in damaging aquatic plants and animals and in the eutrophication of lakes and estuaries.

We would provide some permanence to the conservation benefits of the Conservation Reserve Program. Recall that this is only a 10-year program. Previous Forest Service analyses of forested soil bank land indicated that less than two percent of this acreage reverted back to a commercial crop basis after it had been forested.

In the economy, we would have reduced damage to recreational resources, we would extend the life of water supply and water conveyance facilities, and would provide forest for regional economies.

For example, the Forest Service has noted that in the southeastern part of the United States we need a much greater rate of forestation, if the timber economy in that area is to continue to grow.

Lastly, we would have benefits in terms of energy. We would begin to reduce the rate of greenhouse gas emissions growth. We would stimulate the search for alternatives, research on biomass productivity, and carbon dioxide management generally would be stimulated from private sources.

The point is that the problem is the rate of growth in emissions. There is not likely to be a single chief technical solution to the greenhouse problem, rather progress is more likely to come in small steps.

Some of these small steps can be marginal policy changes which, when summed, have a potent effect in reducing greenhouse gas emissions.

The scientific discussions and the implications of global climate change are yet young. Adopting this policy is a first sane step.

Clearly, it is most desirable to have an international framework for managing emissions. But in the interim we can demonstrate the kind of environmental leadership that has been so critical in catalyzing international action in stratospheric ozone depletion.

In addition, we can take effective action, generate substantial conservation benefits, and ignite the engine of ingenuity in the search of alternatives. Thank you.

[The prepared statement of Dr. Dudek follows:]

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STATEMENT OF DR. DANIEL J. DUDEK SENIOR ECONOMIST, ENVIRONMENTAL DEFENSE FUND

BEFORE THE

SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

concerning

GLOBAL ATMOSPHERIC CHANGE
and
DOMESTIC FOREST RESOURCES

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September 19, 1988

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1 INTRODUCTION

My name is Dr. Daniel J. Dudek. I am a resource economist with the Environmental Defense Fund, a private, non-profit organization. I would like to thank the committee for the opportunity to discuss the offsetting of new CO_2 emissions as one means of beginning the slowing of greenhouse gas emissions. While the policy is completely general and not tied to any specific method of compensating for new CO_2, one option involving the planting of trees appears to be particularly attractive. My testimony will center on this option and its complementarity with the objectives of the Conservation Reserve Program of the Food Security Act of 1985.

2 FORESTS AND CO_2

Considerable attention has been focused on the problem of forests fires in the western United States this year. Drought throughout the West, previously making headlines for devastating the nation's grain harvest, has created tinderbox conditions. These have lead to the burning of over 2 million acres of forest land, an area almost the size of the state of Connecticut. No less intense than the fires is the controversy surrounding fire management policies. While this is certainly a matter worthy of the attention it is receiving, these widespread fires, like the drought, are occurring against the backdrop of global atmospheric change. These currently extreme events offer us a dramatic analog for a possible future. This context creates the imperative for a wider policy focus on the role of forests in global atmospheric change.

2.1 Forests as Sources of CO_2

In investigating the sources of CO_2 emissions, scientists have long discussed the role of deforestation as a major contributor (Whittaker and Likens, 1973). While difficult to measure, it is generally agreed that global deforestation, particularly in the tropics, accounts for approximately 20% of the annual injection of CO_2 into the atmosphere. Annually the forest destruction producing these emissions equals an area slightly larger than the state of Indiana or more than 24.5 million acres. This global total dwarfs our own domestic losses this summer by an order of magnitude.

2.2 Forests under a Changed Climate

Mid-latitude forests have been estimated to contain approximately the same amount of carbon as that currently held in the atmosphere (Jager, 1988). One of the concerns raised by this summer's forest fires is the possible loss of this valuable carbon storage. Previous testimony before this committee on June 23^{rd} focused on the effects of climate change on senstive sectors of our economy and environment. Some of that testimony was drawn from the "Bellagio Report" published by the World Meterological Organization and the United Nations Environment Programme (Jager, 1988).

The scientists producing the Bellagio Report utilized upper and lower bounds for climatic change within which the future climate is 90% likely to occur. For the upper bound representing a rate of change in temperature between 0.8 - 1.0° C per decade, reproductive failure and forest dieback is estimated to begin between 2000 and 2050. The net effect depends upon the speed of change, but is expected to be a significant reduction in forest area and exacerbation of global warming. This reduction in forested area implies the release of large amounts of previously stored carbon to the atmosphere and the loss of annual CO_2 fixing capacity. For the lower bound scenario, temperature would increase at a more moderate 0.06 - 0.07° C per decade and large-scale dieback of existing forests would not occur before 2100. This slower rate of temperature change might permit forest migration, however.

2.3 Forests as a Solution

Of the greenhouse gases emitted to the atmosphere, only CO_2 can be readily removed. The widespread planting of trees has been suggested as one means of removing CO_2 from the atmosphere and storing it in the biomass of the forest (Dyson, 1976). Thus, forests can also contribute significantly to the solution of the greenhouse problem. Sequestering 5 gigatons per year of carbon from the atmosphere, an amount roughly equal to current annual additions, would require between 1.28 billion and 1.65 billion acres of new plantation forests (Marland, 1988). By comparison, the total land area of the United States is 2.27 billion acres.

3 POLICIES TO CONTROL GLOBAL WARMING

Managing the greenhouse problem is best conceived in stages. The first task is to brake the rapid growth of emissions in the atmosphere. For some greenhouse gases, such as the chlorofluorocarbons, this will occur in January of the coming year as the Montreal Protocol takes effect. For others, like the CO_2 produced from fossil fuel combustion, no reduction in emissions growth is expected given the underlying demand for energy. One way to slow emissions growth while allowing growth in energy production is to require all new CO_2 sources to offset their emissions, i.e. new CO_2 sources would have to find compensating CO_2 emission reductions elsewhere. Initially, this approach could be feasibly applied to stationary sources which overall account for 70% of total CO_2 emissions in the U.S.

Offsets could be generated in a variety of ways. Investments in energy conservation would reduce energy demand, reduce fossil fuel burning, and reduce emissions. Investments could also be made in mass transit options in order to reduce mobile sources of CO_2, but these options are likely to be expensive. Emissions could be offset by scrubbing CO_2 emissions from stack gases and then disposing the CO_2. Another possibility is offered by afforestation.

4 FOREST OFFSETS UNDER THE CRP

The Conservation Reserve Program (CRP) is intended to remove highly erodible agricultural land from production. Private landowners offer to convert targeted cropland to non-crop vegetative uses in exchange for an annual government payment. A ten year contract between the owner and the government completes the deal. In addition, the government will subsidize up to 50 percent of the cost of establishing approved conservation practices. The program's goals include 40-45 million acres of cropland under contract in the reserve by 1990. One bill, S. 1521, introduced June 23, 1987 by Senator Nunn and others would expand these figures to 55-65 million acres. In contrast, total U.S. cropland amounts to over 469 million acres. Attaining the program's existing goals will require significant new expenditures as would its expansion.

Offsetting new CO_2 emissions by increasing afforested CRP land would provide a new source for those revenues and facilitate the attainment of both the conservation objectives of the CRP as well as a slowing of CO_2 emissions growth. In establishing the CRP, Congress set a goal that 12.5% of the acreage should be forested. As of this date, less than 1/3rd of that goal has been achieved. In addition, offset expenditures would raise the effective cost of building new power plants making energy efficiency investments relatively more attractive. For illustrative purposes, the offset policy was assessed for all fossil fueled electric generating stations proposed to be constructed between 1987-96 (North American Electric Reliability Council, 1987). Stimulating forest planting under the CRP proved to be the most cost-effective option to reduce CO_2 emissions. Roughly 10 million acres of new trees could offset a decade's worth of new fossil fueled power plants.

5 CRP OFFSET PROGRAM COSTS

Rental payments under the CRP have averaged roughly $50 per acre. In addition, USDA pays up to 1/2 the cost of establishing the protective vegetation. Forested acreage contracts currently account for only 1.6 million acres of the signups under the CRP. Some analysts believe that higher payments are required for an expansion of reforesting contracts. Assuming tree planting at $150 per acre, $100 per acre rental payment, and $25 per acre fertilization costs, 9.26 million acres of trees would cost roughly $1.62 billion to establish.[1] Rental payments would continue over the life of the plant. At $926 million per year, these rental payments would add 0.67 cents per kilowatt hour to utility costs for the set of plants considered. USDA is currently expending in excess of $1.1 billion per year in rental payments alone.[2] Cost-share has added almost $1 billion more.

Assuming a capital cost of $910,000 per megawatt for fossil fuel plants (DOE estimate), the total cost of the plants analyzed is $23.2 billion. Offsetting using only tree planting under somewhat conservative estimates for CO_2 production, uptake, and costs would amount to roughly a 7% increase in capital costs. If USDA continued to pick up its share of expenses including its current rental rate and cost-share, then a utility's per acre establishment cost would drop to approximately $137 per acre. Total program establishment cost to utilities would be close to $1.27 billion or roughly 5.5% of total capital costs. Annual rental payments, however, would drop to $463 million per year or 0.33 cents per kilowatt hour if USDA CRP rental payments were continued.[3] A middle ground policy of providing some payment to conservation targeted acreage would provide an incentive to use those lands for offsets. The justification is the conservation benefits that would additionally accrue. Lastly, no account was taken of any revenues that could be generated through afforestation and subsequent harvest.

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[1] This estimate is based upon the sum of first year costs for planting and fertilization for black locusts, a tree whose CO_2 fixation rate falls in the middle of the range of species previously studied. Fertilization costs may be low. As of May of this year, the average USDA cost-share for tree establishment was $38.20 per acre. If this cost-share were applied to offset acreage, then establishment costs paid by new CO_2 sources would be reduced to $1.27 billion.

[2] Using a 10 percent discount rate and the 10 year life of the CRP, the present value of USDA CRP payments maintained at this level is roughly $6.8 billion. Using the same discount factor and a 50 year life for the generating plants, the present value of utility rental payments for converted cropland without the current CRP payment is approximately $9.2 billion. This latter calculation assumes that all of the proposed generating stations are constructed in a single year. Consequently, the cost estimates have an upward bias.

The estimates of CO_2 uptake are very conservative. Current research indicates fixation rates in the range of 15 mT CO_2/acre/year for silver maples to 22.5 mT CO_2/acre/year for eucalyptus. Within 10-15 years, it is expected that the maximums for several of these species will increase to 30 mT CO_2/acre/year. As fixation rates improve, acreage requirements decline as do costs. Table 1 describes how utility costs vary with tree species and cost sharing by USDA. Establishment costs would range between $1.01 billion and $1.94 billion. On a per kilowatt hour basis, continuing rental costs would fall between 8.0 and 2.7 mills. Clearly, under an offset program there would be substantial incentives for private investment in genetically improving the CO_2 fixation rates of trees. At current rates, the costs per metric ton of CO_2 sequestered are actually quite modest ranging from $0.67 - $1.34 (see Table 1). Even very efficient energy conservation investments would cost between $1.49 - $7.43 per metric ton of CO_2 prevented.

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[3] Under the 10 percent and 50 year assumptions employed above, the present value of utility rental payments would drop to $4.6 billion if current federal CRP payments were continued. Note that this assumes continuation of the CRP beyond its current 10 year authorization.

TABLE 1. UTILITY COST VARIATIONS
BY TREE SPECIES AND PROGRAM

	TREES			
OFFSET PROGRAM	Silver Maple	Black Locust	American Sycamore	Eucalyptus
Total Acreage (millions)	11.11	9.26	8.33	7.41
COSTS	1985 Dollars			
Establishment Cost - No USDA cost share (billions)	1.94	1.62	1.46	1.30
average rental cost per kwh	0.008	0.007	0.006	0.005
present value cost (billions)	11.14	10.82	10.66	10.50
cost per metric ton CO_2	1.34	1.30	1.28	1.26
Establishment Cost - USDA continues cost share (billions)	1.52	1.27	1.14	1.01
average rental cost per kwh	0.004	0.003	0.003	0.003
present value cost (billions)	6.12	5.87	5.74	5.61
cost per metric ton CO_2	0.73	0.70	0.69	0.67

6 CRP OFFSETS ON A STATE BASIS

States may prefer to see that offsetting investments made by new sources are within the state. Since offsets are completely general requiring only commensurate emissions reductions for new sources, such a geographic restriction is feasible. To the extent that offsets provide benefits beyond the slowing of the growth of greenhouse gas concentrations in the atmosphere, states may find such a restriction desirable.

If the CRP option were used, the state would retain the benefits of reduced erosion and improved environmental quality. In addition, the tree species discussed all have economic value beyond energy production. Individual regional economies could benefit from more widespread afforestation. For example, recent assessments by the U.S. Forest Service indicate that the South must dramatically increase its forested acreage if its timber industry is to continue to grow (Ingersoll, 1988).

However, some offset options such as the use of afforestation or the CRP program might be limited in geographic scope both by the growth potential of tree species and by the distribution of erodible crop acreage. Table 2 presents a summary of CRP activity as of June 1988 and the current USDA allocation of acreage eligibility by state. As indicated by the percentage of contracted acreage, less than 1/4 of the targeted acreage has been enrolled overall. Since only roughly 1/4 of the current CRP acreage goals would have to be forested to achieve the aims of this policy, in the aggregate there is more than enough acreage available. Annual precipitation is more likely to be a constraint on unirrigated and therefore more cost-effective forest acreage. The 20 inch isopleth demarks the irrigation boundary and it roughly follows the 100th meridian.

TABLE 2. CONSERVATION RESERVE PROGRAM ACREAGE BY STATE

STATE	ACREAGE CONTRACTED (percentage)	CONTRACTED ACRES	CRP ELIGIBLE ACREAGE (1000s)
AL	33.8	435,163	1,286.0
AZ	0.0	0	196.8
CO	30.6	1,674,322	5,469.4
FL	20.7	92,358	445.2
GA	51.3	511,737	998.3
IA	16.9	1,494,625	8,846.1
IN	10.1	215,548	2,133.6
KY	17.5	358,924	2,054.6
LA	32.1	78,512	244.6
MD	1.6	7,091	439.5
MN	65.8	1,530,997	2,327
MO	24.9	1,303,269	5,226.8
MS	34.5	543,323	1,575.3
NC	6.8	104,374	1,527.8
NV	0.7	1,448	196.9
OH	9.7	148,767	1,529.8
OK	32.0	943,169	2,949.3
TX	22.7	3,157,612	13,932.4
UT	47.1	218,574	463.9
WI	13.8	412,882	2,994.5
TOTAL	24.1	13,232,695	54,837.8

SOURCE: Soil Conservation Service, Conservation Reserve Program Data, June 1, 1988, Washington, D.C., 2 pp.

Table 3 presents the offset acreage required for each state to compensate for CO_2 emissions from cumulative planned new electric generating capacity contrasted with erodible crop acreage.[4] The acreage in Table 5 is defined as cropland with soil erosion rates beyond which sustained agricultural production is impaired.[5] These acreages are estimates of erodible cropland irrespective of the cause of erosion. Nationally, over 173 million acres have been identified as eroding beyond tolerable rates by the Resource Conservation Assessment. The states listed in Table 5 account for only 56% of erodible acreage in the nation.

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[4] The erodible acreage figures are taken from the Resource Conservation Assessment and not the state CRP land eligibility quotas.

TABLE 3. INDIVIDUAL STATE OFFSET ACREAGES

STATE	MEGAWATTS	CO$_2$ (kmT)	ERODIBLE ACRES (1000s)	OFFSET ACREAGE (1000s)	PERCENT
AL	1557	10458.4	2558.8	697.2	27.2
AZ	710	4900.3	187.1	326.7	174.6
CO	899	6204.7	6480.1	413.6	6.4
FL	2678	15136.3	670.2	1009.1	150.6
GA	1641	11325.9	3072.7	755.1	24.6
IA	50	201.2	17833.7	13.4	0.1
IN	1600	10179.6	5244.2	678.6	12.9
KY	1095	7557.5	2412.7	503.8	20.9
LA	540	3727.0	2171.0	248.5	11.4
MD	753	4870.3	602.7	324.7	53.9
MN	1251	8634.2	10102	575.6	5.7
MO	1005	6792.4	7223.7	452.8	6.3
MS	250	1725.5	3009.9	115.0	3.8
NC	690	4762.3	2476.4	317.5	12.8
NV	1865	12469.0	79.1	831.3	1050.9
OH	1300	8972.4	3799.8	598.2	15.7
OK	470	2754.6	3795.2	183.6	4.8
TX	5515	38063.5	20417.2	2537.6	12.4
UT	814	5577.8	392.6	371.9	94.7
WI	60	414.1	4015.6	27.6	0.7
TOTAL	24743	164727	96544.7	10981.8	11.4

As Table 3 indicates, most states would have little difficulty in satisfying an offset requirement by targeting within state erodible lands. In most eastern states, the percentage of erodible land that would have to be converted to forest is a modest percentage of the total area requiring conservation management. Florida is the one striking exception in the East. In the West, erosion problems are much less severe with the result that less CRP qualifying land is available. For Arizona, Nevada, and Utah, the CRP option, if restricted to cropland within the state, would not be feasible. However, these same regions are faced perennially with proposals to retire cropland from active production to capture underlying groundwater rights or to reduce salinity and toxic drainage.

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[5] Soil loss tolerance, the T value, is defined by the U.S. Department of Agriculture's Soil Conservation Service according to the universal soil loss equation. These tolerances are separately developed for both sheet and rill erosion as well as wind erosion.

7 CONCLUSIONS

The policy described in EDF's report, "Offsetting New CO_2 Emissions", has general applicability. CO_2 emissions from planned fossil fueled power plants were selected as an example to demonstrate its operation. While it is much easier to conceive of such a policy applied to stationary sources of CO_2, mobile sources could be included as well, particularly if the policy were operated on a state by state basis. The important point is that feasible policy measures to slow the continued accumulation of greenhouse gases are currently available. Besides providing added stimulus to the expansion of CRP acreage such a program would spur energy efficiency investments, stimulate the search for cheaper methods to control CO_2, and foster research and development in the genetic improvement of trees.

The final question is what do we get for these offsets? The cumulative CO_2 outputs of the listed plants, if built, would account for roughly 3% of total U.S. CO_2 emissions. The point is that we must begin somewhere. Since the problem is the rate of growth in emissions, we must begin to take bites of the problem as opportunities arise, particularly when several public policy objectives can be combined. There is not likely to be a single, cheap technical solution to the greenhouse problem. Rather, progress is more likely to come in small steps. Some of these small steps can be marginal policy changes which when summed have a potent effect in reducing greenhouse gas emissions. While seemingly small, these estimates are based only on the direct offsets and not on any additional conservation induced by the increased energy production costs. If effective, a number of these facilities might not have to be constructed. Further, the retirement of agricultural lands would also generate greenhouse gas emission savings from foregone agricultural operations if the CRP option were elected.

The linkage of a CO_2 offset program with the CRP also answers the thorny question of the fate of the CRP after the ten year contracts expire. Our history with similar land retirement programs indicates a general failure in following through. Previous efforts aimed at the creation of a soil bank proved to be temporary as congressional support waned. Under these previous programs, cropland conversions to forested acreage tended to be more permanent. An offset policy could provide permanence to the CRP and secure lasting environmental benefits by providing a stream of income beyond the 10 year life of the program for forested acreage. Finally, offsets would stimulate the search for new and cheaper ways of eliminating CO_2 emissions, a pressing national priority.

While the scientific discussions of the implications of global climate change are yet young, adopting this policy is a first sane step toward reducing the accumulation of greenhouse gases. Clearly, it is most desirable to have an international framework for managing emissions, but in the interim we can demonstrate the kind of environmental leadership so instrumental in achieving international action to protect stratospheric ozone. In addition, we can take effective action, generate substantial conservation benefits, and ignite the engine of ingenuity in search of alternatives.

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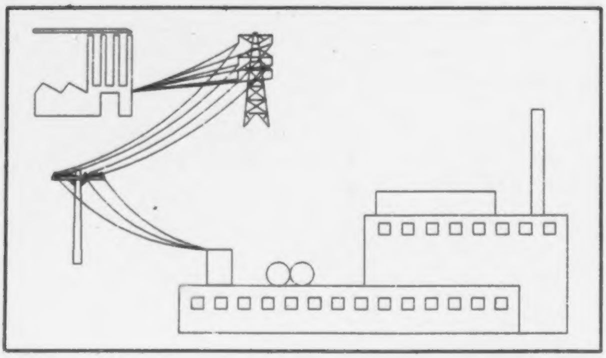
Offsetting New CO_2 Emissions



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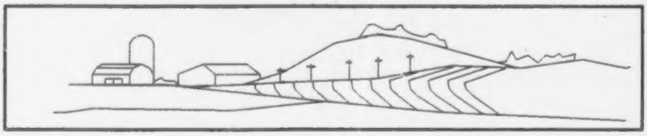

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ENVIRONMENTAL DEFENSE FUND

OFFSETTING NEW CO_2 EMISSIONS

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1 SUMMARY

This report analyzes a policy to slow the increase of CO_2 emissions in the atmosphere. In its essence, new CO_2 sources would either prevent their emissions or procure compensating emissions reductions. Electric generating power plants are used as an example to demonstrate the mechanics of the policy and the choices faced by sources. For instance, CO_2 emissions could be treated at the source through various combinations of CO_2 scrubbing and disposal. Emission reduction options could also include investments in energy conservation sufficient to offset the proposed CO_2 increases or afforestation to sequester the increased atmospheric carbon. Focusing on this latter option, the report demonstrates that the increased CO_2 emissions from planned power plants could be offset by the planting of roughly 10 million acres of forest land.

This approach could also provide the opportunity to meld several public policy objectives. Currently, the nation has embarked on an ambitious effort to retire erodible cropland under the Conservation Reserve Program (CRP). The CRP allows landowners to place cropland under vegetative cover or trees as part of a 10 year contract in exchange for an annual rental payment. The goals of reducing erosion, surplus agricultural production, and the greenhouse warming are shown to be highly compatible. By providing an additional financial incentive, an offset program could boost lagging forest signups under the CRP. Regionally, the added forested acreage could help to satisfy timber, wildlife habitat, and recreational demands in addition to conservation goals. CO_2 offsetting forest acreage would be approximately 1/4 of the land authorized for the CRP. These increases in forest land could be secured at a cost between \$1.01 - \$1.94 billion depending upon the cost-share policy.

The offset policy is assessed for all fossil fueled electric generating stations proposed to be constructed between 1987-96. Options including biomass energy plantations, energy conservation investments, CO_2 scrubbing, and afforestation were evaluated. Stimulating forest planting under the CRP is the most cost-effective option to reduce CO_2 emissions. Besides providing added stimulus to the expansion of CRP acreage such a program would spur energy efficiency investments, stimulate the search for cheaper methods to control CO_2, and foster research and development in the genetic improvement of trees.

While the scientific discussions of the implications of global climate change are yet young, adopting this policy is a first sane step toward reducing the accumulation of greenhouse gases. Clearly, it is most desirable to have an international framework for managing emissions, but in the interim we can demonstrate the kind of environmental leadership so instrumental in achieving international action to protect stratospheric ozone. In addition, we can take effective action, generate substantial conservation benefits, and ignite the engine of ingenuity in search of alternatives.

2 INTRODUCTION[1]

This year public attention has been focused on the portent of global change. International consensus concerning depletion of the stratospheric ozone layer developed and agreement to restrict the production of chlorofluorocarbons (CFCs) was achieved. The huge seasonal ozone depletions over the Antarctic continent visibly demonstrated the human capacity for dramatic alteration of the biosphere. As awareness of this problem has increased, recognition of the dual role of CFCs as both ozone depleters and greenhouse gases has also developed. The unusual weather patterns of the Summer of 1988 have created crisis conditions for many weather sensitive sectors of the economy. Drought affected much of the Midwest and Great Plains regions of the U.S. severely reducing crop yields. River flows have approached historic lows seriously restricting barge traffic and drastically reducing riparian habitat. Mortality among fish and waterfowl populations has been excessively high. More recently, the western states have been ravaged by forest fires increasing the drought's devastation and adding to the emissions of CO_2, the single most important greenhouse gas.

These events coupled with recent scientific assessments presented at Villach, Toronto, and before the Senate Committee on Energy and Natural Resources have prompted policy makers to assess the appropriate response of governments. Legislative initiatives such as S. 2667 introduced by Senator Wirth with several co-sponsors and S. 2666 introduced by Senators Stafford and Baucus and others are the beginning of this response. Many recognize the importance of energy efficiency improvements and the reduction of fossil fuel combustion. Ultimate goals for fossil fuel reduction have been set at roughly 50% in order to stabilize the atmosphere.[2] However, most policy initiatives remain in the planning or research stages.

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[1] The author has benefited from the assistance of Joshua Foster, an intern from the University of Massachusetts, Amherst, in the preparation of this report. Complete responsibility for its contents remain with the author however.

[2] A recent international conference, "The Changing Atmosphere: Implications for Global Security", brought scientists together in Toronto in June of 1988. The consensus was that a 20% reduction in fossil fuel combustion would be both desirable and attainable by 2005. That same meeting also discussed the 50% goal.

The greenhouse policy problem is very much like driving a car. The driver has a number of options to control the car much in the same manner that policies guide society. In both cases, a combination of actions usually produces the most effective results. Some policies steer society toward different energy choices through changes in incentives. Others would accelerate research and development to avoid future catastrophes. The policy evaluated in this report would begin the long process of slowing greenhouse gas emissions and averting some of the warming. The policy debate is focused clearly on the best mix of strategies.

3 GREENHOUSE POLICIES

Managing the greenhouse problem is best conceived in stages. The first task is to brake the rapid growth of emissions in the atmosphere. For some greenhouse gases, such as the chlorofluorocarbons, this will occur in January of the coming year as the Montreal Protocol takes effect. For others, like the CO_2 produced from fossil fuel combustion, no reduction in emissions growth is expected given the underlying demand for energy. Investments in energy conservation have allowed the U.S. economy to grow significantly while keeping total energy consumption virtually flat over the 1973-87 period (Hatsopoulos, et al., 1988). However, real energy prices have also fallen and diminished the discipline of the market. The mix of fuels used in energy production is another critical determinant of emissions. Many conventional energy analysts forecast increasing reliance on coal for energy beyond its current 24% share of the U.S. market.

One way to slow emissions growth while allowing growth in energy production is to require all new CO_2 sources to offset their emissions, i.e. new CO_2 sources would have to find compensating CO_2 emission reductions elsewhere. Initially, this approach could be feasibly applied to stationary sources which overall account for 70% of total CO_2 emissions in the U.S.

4 OFFSETS

Offsets could be generated in a variety of ways. Investments in energy conservation would reduce energy demand, reduce fossil fuel burning, and reduce emissions. Such offsetting investments need not be limited to the service region of an individual utility. If energy conservation investments are more effective in northern regions, then these opportunities might be exploited first. Investments could also be made in mass transit options in order to reduce mobile sources of CO_2, but these options are likely to be expensive. Emissions could also be offset by scrubbing CO_2 emissions from stack gases and then disposing the CO_2. A currently more feasible possibility is offered by afforestation. The following sections describe and analyze the feasibility of several potential offset options. All of the examples presume an offset ratio of 1-to-1, but any ratio could be implemented. In particular, if the offset option is uncertain in its effectiveness, then offsets greater than 1-to-1 would be desirable.

Under this policy, offset proposals could be reviewed and certified by existing state or federal regulatory authorities. Guidance and technical assistance to state-level authorities could be collected, disseminated and developed by federal agencies. The identification and evaluation of alternative offset opportunities would be a valuable federal contribution.

4.1 Biomass Offsets

Of the greenhouse gases emitted to the atmosphere, only CO_2 can be readily removed. The widespread planting of trees has been suggested as one means of removing CO_2 from the atmosphere and storing it as carbon in the biomass of the forest (Dyson, 1976). Sequestering 5 gigatons per year of carbon from the atmosphere, an amount roughly equal to current annual additions, would require between 1.28 billion and 1.65 billion acres of new plantation forests (Marland, 1988). By comparison, the total land area of the United States is 2.27 billion acres.

Alternatively, if the productivity of existing forests were doubled we could achieve the same result from existing forests through increased uptake of CO_2. These increases would have to be achieved through genetic improvements, management, and fertilization. However, existing studies of the use of trees to control the greenhouse problem are extremely restrictive assessments because they require that the CO_2 problem be solved by one approach alone. Their virtue lies in the demonstration of the lack of technical or physical limits to the use of large-scale biomass offsets.

Some have also noted that the deforestation of tropical regions is a significant source of CO_2 (Whittaker and Likens, 1973). Stopping deforestation would remove this source of emissions, but would not provide any compensation for new emissions. However, expansion of forested area would produce offsetting reductions of CO_2. Joint investments between utilities and timber companies or the Forest Service would be possible. Another opportunity is offered by the Conservation Reserve Program (CRP) created by the Food Security Act of 1985.

4.1.1 The Conservation Reserve Program

The CRP is intended to remove highly erodible agricultural land from production. Private landowners offer to convert targeted cropland to non-crop vegetative uses in exchange for an annual government payment. A ten year contract between the owner and the government completes the deal. In addition, the government will subsidize up to 50 percent of the cost of establishing approved conservation practices. The program's goals include 40-45 million acres of cropland under contract in the reserve by 1990. One bill, S. 1521, introduced June 23, 1987 by Senator Nunn and others would expand these figures to 55-65 million acres. Total U.S. cropland amounts to over 469 million acres. Some of the program has been targeted for afforestation as well. Attaining the program's existing goals will require significant new expenditures as would its expansion.

Offsetting new CO_2 emissions by increasing afforested CRP land would provide a new source for those revenues and facilitate the attainment of both the conservation objectives of the CRP as well as a slowing of CO_2 emissions growth. In establishing the CRP, Congress set a goal that 12.5% of the acreage should be forested. As of this date, less than 1/3rd of that goal has been achieved. In addition, offset expenditures would raise the effective cost of building new power plants making energy efficiency investments relatively more attractive.

4.1.2 Feasibility of Biomass Offsets

Table 1 presents the results of series of calculations to assess the potential feasibility of offsetting new sources using tree planting alone. Planned coal and oil-fired generating stations were taken from the 1987 Reliability Assessment published by the North American Electric Reliability Council. Plants were assumed to operate at average industry-wide capacity rates (65% for new coal plants) and to have efficiencies common for such facilities (a conservative 33% for coal).[3] Estimates of CO_2 emissions were derived by assuming a common energy content in the fuels for each plant type. The resulting CO_2 emissions by year and plant type are displayed in Table 1.

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[3] Low efficiencies lead to an upward bias in the amount of coal used and CO_2 produced. As a result, the technical and economic feasibility analysis for offsets is conservative.

TABLE 1. PLANNED COAL AND OIL-FIRED ELECTRIC GENERATING CAPACITY INCREASES BY STATE THROUGH 1996

YEAR	COAL-FIRED			OIL-FIRED			ACREAGE
	STATE	MEGAWATTS	CO_2 (metric tons)	STATE	MEGAWATTS	CO_2 (metric tons)	
1987	CO	64		UT	7		
	FL	415		UT	7		
	FL	550					
	GA	833					
	MN	800					
	MN	51					
	UT	800					
	Subtotal	3513	24248087	Subtotal	14	56338	1620161
1988	FL	550		MD	6		
	IN	1300		MD	6		
	TX	344					
	Subtotal	2194	15142589	Subtotal	13	50704	1012886
1989	AL	666					
	AZ	360					
	GA	808					
	Subtotal	1834	12657934				843862
1991	AL	666					
	AZ	350					
	KY	495					
	OH	1300					
	OK	300					
	TX	750					
	Subtotal	3861	26647920				1776827
1992	KY	600		IA	50		
	MD	640		IN	80		
	MO	75					
	NC	690					
	TX	498					
	Subtotal	2503	17275250	Subtotal	130	523136	1186589
1993	TX	750		AL	50		
				IN	60		
				NV	70		
	Subtotal	750	5176363	Subtotal	180	724343	393380
1994	CO	485		AL	50		
	MO	55		FL	75		
	MO	630		FL	75		
	MO	55		FL	75		
	NV	50		FL	75		
	TX	498		FL	75		
	TX	400		FL	75		
	TX	750		IN	80		
	WI	60		NV	70		
				UNK	60		
				UNK	60		
	Subtotal	2983	20588123	Subtotal	770	3098576	1579113
1995	AL	125		FL	75		
	CO	350		FL	50		
	MS	250		FL	213		
	NV	750		IN	80		
	NV	125		UNK	60		
				UNK	60		
	Subtotal	1600	11043909	Subtotal	538	2164979	880826
1996	LA	540		FL	75		
	MN	400		FL	75		
	MO	70		FL	75		
	MO	70		FL	75		
	NV	750		FL	75		
	NV	50		MD	100		
	TX	645		MO	50		
	TX	680		OK	170		
	TX	200		UNK	60		
				UNK	60		
				UNK	60		
				UNK	60		
	Subtotal	3405	23500690	Subtotal	935	3762556	1817849
TOTALS		22643	156277865		2580	10380632	11110566

SOURCE: Planned electric generating capacity increases were taken from the North American Electric Reliability Council, 1987.

The feasibility of afforestation was assessed by using estimates of the rate of uptake of CO_2 (15 metric tons of CO_2 per acre per year) by Silver Maples, the least efficient of the commonly found large trees previously studied. The resulting annual offsetting acreages are shown by year. For the period 1987-96, all new CO_2 emissions from the production of electricity could be offset by roughly 11.1 million acres of trees. Table 2 presents the acreages of various tree species required to offset the emissions of the planned electrical generating stations. Total acreages vary from 11.1 to 7.4 million acres depending upon the efficiency of CO_2 fixation. Since it is most likely that any offset program would employ a range of species in different locations, the mid-range estimate of 9.26 million acres is quite reasonable. This figure is less than $1/4^{th}$ of the CRP's 1990 acreage goal of 40 million acres and only $1/6^{th}$ of Senator Nunn's proposed CRP expansion.

TABLE 2. ACREAGE VARIATION BY TREE SPECIES

YEAR	CO_2 (million metric tons)	TREES			
		Silver Maple	Black Locust	American Sycamore	Eucalyptus
		millions of acres			
1987	24.3	1.62	1.35	1.21	1.08
1988	15.2	1.01	0.84	0.76	0.68
1989	12.7	0.84	0.70	0.63	0.56
1991	26.6	1.78	1.48	1.33	1.18
1992	17.8	1.19	0.99	0.89	0.79
1993	5.9	0.39	0.33	0.30	0.26
1994	23.7	1.58	1.32	1.18	1.05
1995	13.2	0.88	0.73	0.66	0.59
1996	27.3	1.81	1.51	1.36	1.21
TOTALS	166.7	11.11	9.26	8.33	7.41

4.1.3 CRP Offset Program Costs

These calculations need to be expanded to include a wider variety of tree species and to account for differences in the productivity of available soils. In addition, the energy content of fuels should be adjusted by region. Bituminous coal was assumed for these calculations. Further, CO_2 emission increases for natural gas fired facilities, non-utility generators, and other sources need to be included. However, the figures presented in this discussion are reasonable first cut estimates. Rental payments under the CRP have averaged roughly $50 per acre.

In addition, USDA pays up to 1/2 the cost of establishing the protective vegetation. Forested acreage contracts currently account for only 1.6 million acres of the signups under the CRP. Some analysts believe that higher payments are required for an expansion of reforesting contracts. Assuming tree planting at $150 per acre, $100 per acre rental payment, and $25 per acre fertilization costs, 9.26 million acres of trees would cost roughly $1.62 billion to establish.[4] Rental payments would continue over the life of the plant. At $926 million per year, these rental payments would add 0.67 cents per kilowatt hour to utility costs for the set of plants considered. USDA is currently expending in excess of $1.1 billion per year in rental payments alone.[5] Cost-share has added almost $1 billion more.

Assuming a capital cost of $910,000 per megawatt for fossil fuel plants (DOE estimate), the total cost of the plants in Table 1 is $23.2 billion. Offsetting using only tree planting under somewhat conservative estimates for CO_2 production, uptake, and costs would amount to roughly a 7% increase in capital costs. If USDA continued to pick up its share of expenses including its current rental rate and cost-share, then a utility's per acre establishment cost would drop to approximately $137 per acre. Total program establishment cost to utilities would be close to $1.27 billion or roughly 5.5% of total capital costs. Annual rental payments, however, would drop to $463 million per year or 0.33 cents per kilowatt hour if USDA CRP rental payments were continued.[6] A middle ground policy of providing some payment to conservation targeted acreage would provide an incentive to use those lands for offsets. The justification is the conservation benefits that would additionally accrue. No account is taken of any revenues that could be generated through afforestation and subsequent harvest.

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[4] This estimate is based upon the sum of first year costs for planting and fertilization. Fertilization costs may be low. As of May of this year, the average USDA cost-share for tree establishment was $38.20 per acre. If this cost-share were applied to offset acreage, then establishment costs paid by new CO_2 sources would be reduced to $1.27 billion.

[5] Using a 10 percent discount rate and the 10 year life of the CRP, the present value of USDA CRP payments maintained at this level is roughly $6.8 billion. Using the same discount factor and a 50 year life for the generating plants, the present value of utility rental payments for converted cropland without the current CRP payment is approximately $9.2 billion. This latter calculation assumes that all of the proposed generating stations are constructed in a single year. Consequently, the cost estimates have an upward bias.

[6] Under the 10 percent and 50 year assumptions employed above, the present value of utility rental payments would drop to $4.6 billion if current federal CRP payments were continued. Note that this assumes continuation of the CRP beyond its current 10 year authorization.

The estimates of CO_2 uptake are very conservative. Current research indicates fixation rates in the range of 15 mT CO_2/acre/year for silver maples to 22.5 mT CO_2/acre/year for eucalyptus. Within 10-15 years, it is expected that the maximums for several of these species will increase to 30 mT CO_2/acre/year. As fixation rates improve, acreage requirements decline as do costs. Table 3 describes how utility costs vary with tree species and cost sharing by USDA. Establishment costs would range between $1.01 billion and $1.94 billion. On a per kilowatt hour basis, continuing rental costs would fall between 8.0 and 2.7 mills. Clearly, under an offset program there would be substantial incentives for private investment in genetically improving the CO_2 fixation rates of trees. At current rates, the costs per metric ton of CO_2 sequestered are actually quite modest ranging from $0.67 - $1.34 (see Table 3).

TABLE 3. UTILITY COST VARIATIONS
BY TREE SPECIES AND PROGRAM

	TREES			
PROGRAM	Silver Maple	Black Locust	American Sycamore	Eucalyptus
	1985 Dollars			
Establishment Cost - No USDA cost share (billions)	1.94	1.62	1.46	1.30
average rental cost per kwh	0.008	0.007	0.006	0.005
present value cost (billions)	11.14	10.82	10.66	10.30
cost per metric ton CO_2	1.34	1.30	1.28	1.26
Establishment Cost - USDA continues cost share (billions)	1.52	1.27	1.14	1.01
average rental cost per kwh	0.004	0.003	0.003	0.003
present value cost (billions)	6.12	5.87	5.74	5.61
cost per metric ton CO_2	0.73	0.70	0.69	0.67

4.1.4 Applying CRP Offsets on a State Basis

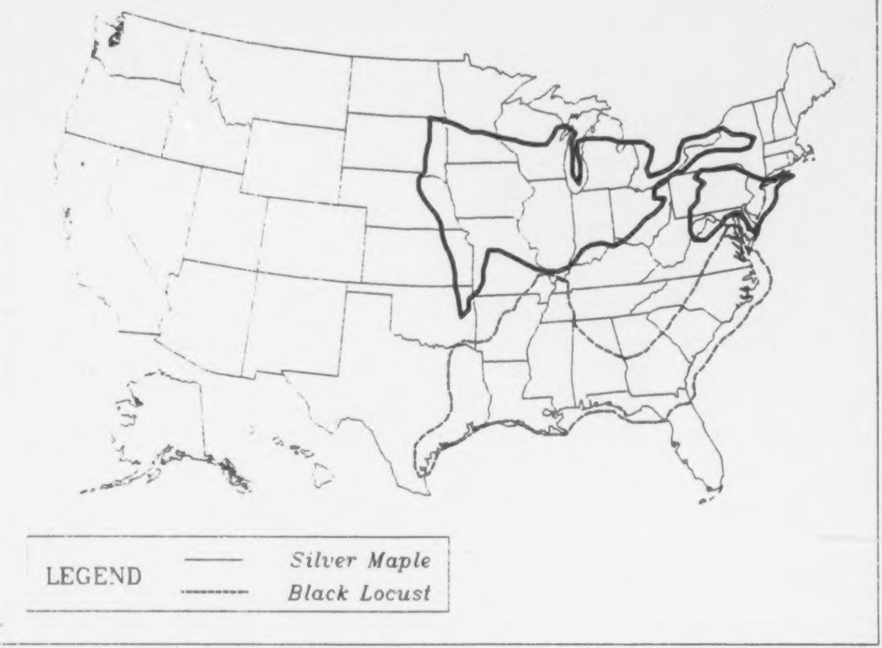
While from an atmospheric standpoint the location of offsets or their form is immaterial, states may prefer to see that offsetting investments made by new sources are within the state. Since offsets are completely general requiring only commensurate emissions reductions for new sources, such a geographic restriction is feasible. To the extent that offsets provide benefits beyond the slowing of the growth of greenhouse gas concentrations in the atmosphere, states may find such a restriction desirable. For example, conservation investments may be made to reduce demand to allow the retirement of older less efficient generating stations. Under a state offset program, the industries, utilities, and residents of the state would capture the benefits from such conservation investments.

If the CRP option were used, the state would retain the benefits of reduced erosion and improved environmental quality. In addition, the tree species discussed all have economic value beyond energy production. For example, the silver maple has commercial uses in furniture, box, crate and handle production as well as for pulpwood. The American Sycamore can also be used in millwork, flooring, and other hardwood products. Individual regional economies could benefit from more widespread afforestation. For example, recent assessments by the U.S. Forest Service indicate that the South must dramatically increase its forested acreage if its timber industry is to continue to grow (Ingersoll, 1988).

However, some offset options such as the use of afforestation or the CRP program might be limited in geographic scope both by the growth potential of tree species and by the distribution of erodible crop acreage. Figure 1 depicts high growth regions for two tree species, silver maples and black locusts. These regions were defined by field research conducted by Oak Ridge National Laboratory to determine the energy potential of tree plantations (Ranney, et al., 1987).

Species evaluated for biomass energy production potential include cottonwoods, poplars, black locust, silver maple, and eucalyptus. Most of these species were selected for their high growth rates as well as regional suitability. Since a significant component of the cost of establishing a plantation is land preparation, feasibility studies have emphasized regions where marginal unused agricultural lands predominate. As Figure 1 indicates, these factors have focused research attention on the eastern United States.

Figure 1. Regions With High Growth Potential



SOURCE: Ranney, et al., 1987.

Use of the CRP option by state is potentially restricted by the availability of eligible cropland. Table 4 presents a summary of CRP activity as of June 1988 and the current USDA allocation of acreage eligibility by state. As indicated by the percentage of contracted acreage, less than 1/4 of the targeted acreage has been enrolled overall. Since only roughly 1/4 of the current CRP acreage goals would have to be forested to achieve the aims of this policy, in the aggregate there is more than enough acreage available. Since acreage eligibility is defined by USDA regulations and therefore subject to change, state level application of CRP CO_2 offsets is best considered from the standpoint of the total number of acres requiring conservation management.

TABLE 4. CONSERVATION RESERVE PROGRAM ACREAGE BY STATE

STATE	ACREAGE CONTRACTED (percentage)	CONTRACTED ACRES	CRP ELIGIBLE ACREAGE (1000s)
AL	33.8	435,163	1,286.0
AZ	0.0	0	156.8
CO	30.6	1,674,322	5,469.4
FL	20.7	92,358	443.2
GA	51.3	511,737	998.3
IA	16.9	1,494,625	8,846.1
IN	10.1	215,348	2,133.6
KY	17.5	358,924	2,054.6
LA	32.1	78,512	244.6
MD	1.6	7,091	439.5
MN	65.8	1,530,997	2,327
MO	24.9	1,303,269	3,226.8
MS	34.5	543,323	1,575.3
NC	6.8	104,374	1,327.8
NV	0.7	1,448	196.9
OH	9.7	148,767	1,529.8
OK	32.0	943,169	2,949.3
TX	22.7	3,157,612	13,932.4
UT	47.1	218,574	463.9
WI	13.8	412,882	2,994.5
TOTAL	24.1	13,232,695	54,837.8

SOURCE: Soil Conservation Service, Conservation Reserve Program Data, June 1, 1988, Washington, D.C., 2 pp.

Table 5 presents the offset acreage required for each state to compensate for CO_2 emissions from cumulative planned new electric generating capacity contrasted with erodible crop acreage.[7] The acreage in Table 5 is defined as cropland with soil erosion rates beyond which sustained agricultural production is impaired.[8] These acreages are estimates of erodible cropland irrespective of the cause of erosion. Nationally, over 173 million acres have been identified as eroding beyond tolerable rates by the Resource Conservation Assessment. The states listed in Table 5 account for only 56% of erodible acreage in the nation.

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[7] The totals in Table 5 may not exactly correspond with those in preceding tables since plants without specific state locations have been deleted from the list. These plants were identified as UNK in Table 1 for example. These differences, however, are slight. The erodible acreage figures are taken from the Resource Conservation Assessment and not the state CRP land eligibility quotas.

[8] Soil loss tolerance, the T value, is defined by the U.S. Department of Agriculture's Soil Conservation Service according to the universal soil loss equation. These tolerances are separately developed for both sheet and rill erosion as well as wind erosion.

TABLE 5. INDIVIDUAL STATE OFFSET ACREAGES

STATE	MEGAWATTS	CO_2 (kmT)	ERODIBLE ACRES (1000s)	OFFSET ACREAGE (1000s)	PERCENT
AL	1557	10458.4	2558.8	697.2	27.2
AZ	710	4900.3	187.1	326.7	174.6
CO	899	6204.7	6480.1	413.6	6.4
FL	2678	15136.3	670.2	1009.1	150.6
GA	1641	11325.9	3072.7	755.1	24.6
IA	50	201.2	17833.7	13.4	0.1
IN	1600	10179.6	5244.2	678.6	12.9
KY	1095	7557.5	2412.7	503.8	20.9
LA	540	3727.0	2171.0	248.5	11.4
MD	753	4870.3	602.7	324.7	53.9
MN	1251	8634.2	10102	575.6	5.7
MO	1005	6792.4	7223.7	452.8	6.3
MS	250	1725.5	3009.9	115.0	3.8
NC	690	4762.3	2476.4	317.5	12.8
NV	1865	12469.0	79.1	831.3	1050.9
OH	1300	8972.4	3799.8	598.2	15.7
OK	470	2754.6	3795.2	183.6	4.8
TX	5515	38063.5	20417.2	2537.6	12.4
UT	814	5577.8	392.6	371.9	94.7
WI	60	414.1	4015.6	27.6	0.7
TOTAL	24743	164727	96544.7	10981.8	11.4

As Table 5 indicates, most states would have little difficulty in satisfying an offset requirement by targeting within state erodible lands. In most eastern states, the percentage of erodible land that would have to be converted to forest is a modest percentage of the total area requiring conservation management. Florida is the one striking exception in the East. In the West, erosion problems are much less severe with the result that less CRP qualifying land is available. For Arizona, Nevada, and Utah, the CRP option, if restricted to cropland within the state, would not be feasible. However, these same regions are faced perennially with proposals to retire cropland from active production to capture underlying groundwater rights or to reduce salinity and toxic drainage.

4.2 Biomass Energy Plantation Offsets

Trees could also be produced in an intensive plantation style of cultivation. For both Douglas fir and loblolly pine, dramatic increases in productivity of 26% and more than 100% respectively have been documented (Farnum, et al., 1983). However, at the least, widespread conversion of existing forested areas to biomass plantations could increase the net flux of carbon to the atmosphere (Cropper and Ewel, 1987). From an ecological point of view such wholesale conversions to monoculture would be disastrous. Fortunately, current economic evaluations of this energy source tend to favor cropland conversion since land preparation costs are dramatically reduced.

Since the energy crisis of the early 70's, substantial research has been devoted to the evaluation of the potential to supply the Nation's energy demand from biomass. Results from the Department of Energy's research program indicate that plantation management could sequester carbon at a cost between $5.00-$10.00 per metric ton of CO_2 (Ranney, et al., 1987). These cost figures are those for the plantation and its operation only.

4.3 Energy Conservation Offsets

The use of energy conservation investments to reduce the demand for energy and thus avoid the construction of new expensive generating capacity is well known. Recently, a consortium of New England utilities announced the most ambitious national plan to date. Northeast Utilities' plan, unveiled in May, will spend more per capita than any other conservation investment program in the U.S. (Wald, 1988). The costs of many of the options to be financed by the program are expected to range between 2-3 cents per kilowatt-hour saved. In CO_2 emission reduction terms, this amounts to $12.30 - $18.45 per metric ton of CO_2 emissions prevented assuming coal-fired generation. These conservation investments would also reduce the underlying demand for new generating stations and the demand for offsets. The offset policy itself should increase demand for energy conservation investments as it is likely that any offset policy would result in a mix of options actually selected.

Over the years a wide variety of energy conservation investments and their costs have been assembled. Some energy conservation investments combine demand reduction and CO_2 sequestering. For example, planting shade trees around homes to reduce air conditioning demand has been suggested. This option has been estimated to cost between $1.49 - $7.43 per metric ton of CO_2 prevented (Rosenfeld, et al., 1988).

4.4 CO_2 Scrubbing and Disposal

Another possibility for offsets would be the more conventional approach of treating emissions at the source through the scrubbing of stack gases. The most economically promising of the scrubbing technologies for CO_2 consists of an absorption and stripping process using monoethanolamine (MEA) (Albanese and Steinberg, 1980).

The critical determinant of cost and feasibility is the CO_2 disposal method however. Disposal options primarily involve deep ocean discharge in solid, liquid or gaseous form. At the 90% removal level, electric generating costs would increase 3-6 times for a modern coal-fired 200 megawatt plant depending upon disposal option. Clearly, these estimates are beyond those for alternative offset options. However, technologic change, in part induced by policies such as an offset requirement, is expected as evidenced by new developments (Chemical Marketing Reporter, 1988).

5 CONCLUSIONS

The policy described in this report has general applicability. CO_2 emissions from planned fossil fueled power plants were selected as an example to demonstrate the offset policy. While it is much easier to conceive of such a policy applied to stationary sources of CO_2, mobile sources could be included as well, particularly if the policy were operated on a state by state basis. The important point is that feasible policy measures to slow the continued accumulation of greenhouse gases are currently available. For stationary sources, an important issue is the rate of turnover of power plants. This policy, and others which effectively increase the cost of new plants, may tend to reduce the rate of turnover and thus extend the useful life of existing equipment. To the extent that new plants are more efficient, CO_2 reductions from increasing average efficiency would be slowed. On the other hand, increased generating costs make energy demand management options like conservation investments relatively more attractive.

The final question is what do we get for these offsets? The cumulative CO_2 outputs of the listed plants, if built, would account for roughly 3% of total U.S. CO_2 emissions. The point is that we must begin somewhere. Since the problem is the rate of growth in emissions, we must begin to take bites of the problem as opportunities arise, particularly when several public policy objectives can be combined. There is not likely to be a single, cheap technical solution to the greenhouse problem. Rather, progress is more likely to come in small steps. Some of these small steps can be marginal policy changes which when summed have a potent effect in reducing greenhouse gas emissions. While seemingly small, these estimates are based only on the direct offsets and not on any additional conservation induced by the increased energy production costs. If effective, a number of these facilities might not have to be constructed. Further, the retirement of agricultural lands would also generate greenhouse gas emission savings from foregone agricultural operations if the CRP option were elected.

The linkage of a CO_2 offset program with the CRP also answers the thorny question of the fate of the CRP after the ten year contracts expire. Our history with similar land retirement programs indicates a general failure in following through. Previous efforts aimed at the creation of a soil bank proved to be temporary as congressional support waned. Under these previous programs, cropland conversions to forested acreage tended to be more permanent. An offset policy could provide permanence to the CRP and secure lasting environmental benefits by providing a stream of income beyond the 10 year life of the program for forested acreage. Finally, offsets would stimulate the search for new and cheaper ways of eliminating CO_2 emissions, a pressing national priority.

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Senator **Wirth**. Dr. Dudek, thank you very much. Dr. Marland, let me start, if I might, with you.

First of all, you have heard the proposals of Mr. Moll and Dr. Dudek, and you have done a lot of analysis along these lines, obviously, from your testimony. Do you have any comments on the proposals that the two of them have made and how realistic those are? And what the impact of those might be?

Second, going back to your numbers of five tons of carbon per person equals 15 acres of forest, 50 percent larger than the land area of the United States, obviously we are not going to reforest ourselves out of a global warming problem.

But what would be a realistic set of steps for us to be taking, if in fact—as I believe Dr. Dudek is correct in suggesting that we have to put together a string of a lot of small steps, there is going to be no simple or single solution to the problem of global warming.

So two questions in reaction to them. And second, what do you think in the area of forestation would be the best policy for us to be pursuing?

Dr. **Marland**. I think we have to be careful, and I guess what I have tried to make clear, is the difference between extensive forestry and intensive forestry.

Given the choice, ultimately, we can increase the area of forests or we can increase the productivity of existing forests. And we have some options to do both. But I think my main point is that we cannot simply increase the area of forests. That is not adequate. That is not going to solve the problem. But it does take you a little way.

The second step in reaction to Dr. Dudek's comments, I think we have to be careful, too. I do not know very much about the Conservation Reserve Program, but if it is land that is being abandoned from agriculture, my suspicion is that it is not very good land.

To get very high growth rates of trees and the kinds of things I am talking about, with 7.5 tons of carbon per hectare, and I think it was the kind of number he must have been using because suggesting 10 million acres as an offset implies very high growth rates for trees, and that is something that is not going to happen on poor or marginal land.

So I think it has to be explored in some depth. What is the quality of the land that is available? What kind of growth rates one might expect to get? It is not just how much land but what is the quality of land and what you might be able to do with it.

I guess my main conclusion, from the numbers I have come up with, is that if we are going to do anything with forestry it is going to have to be intensive management. There are lots of good reasons for planting trees. But if we really want to do it in a substantive way, and believe that we are having an impact on global carbon dioxide, it is either going to be really huge areas or we are going to have to do some research and understand how fast can we get those trees to grow. The next question is, Do we want them to just grow, or are we going to try to use them as biomass fuels?

If I may, there is one thing I wanted to throw out and I forgot in my anxieties, in my initial shot, the discussion of the Yellowstone fires, it gives us another perspective on what we are talking about.

I talked to some of the people out there and if you can guess that the fires were burning 25 short tons per acre of fuel, you take a million and a half acres of forest, that is about 3 percent of U.S. fossil fuel emissions of CO_2. That gives you an idea of how all these things go. Three percent of the annual emissions.

My own suspicion is that over a period of time that is not very important, because there must be ups and downs in the total volume of forest burned. But if we are talking about the long-term trend, the amount of forest fires probably does not vary too much from year to year.

That is not an important contribution in terms of CO_2 to the atmosphere. But it does give you an idea of what that volume of forest means in terms of what we are doing by burning the fossil fuels.

Did I answer the questions?

Senator WIRTH. Mr. Moll, I am struck by—I talk to a lot of groups about global warming, and I think all of us do, and there is often a citizen question, what do I do?

I am struck by your proposal and your reference to the idea of individual entitlement or citizen entitlement. People can in fact do something.

Thinking about the experience of the Israelis, the enormous sense of a participation in Israel in part through planting of trees. People have a sense that they are responsible, and they have a stake in this, and that they have really made a step.

I think it is a very attractive notion. How you go about packaging that and putting it together is another issue. But maybe that is being done now. Is it somewhere? Is there a major national program now for forestation?

Is there a program that they are looking at cities and looking at school groups and botanic garden groups and garden club groups and so on? Is there something like this going on?

Mr. MOLL. Well, the National Urban Forest Council is made up of a number of those groups, and there are places like the example of Andy Lipkus, a group called Tree People in Los Angeles that, to answer some other emissions questions, tried to plant a million trees by the Olympics.

Senator WIRTH. That is called Tree People of Los Angeles?

Mr. MOLL. Yes.

Senator WIRTH. I was in West Hollywood the other day.

Mr. MOLL. They have helped it a lot actually by putting them on the air, but they were successful by the last Olympics 4 years ago at planting a million trees.

It was really their Department of Transportation that asked them to do it, the city's Department of Transportation. Because they could not meet the restrictions put on them.

Senator WIRTH. Now, is this program being repeated? Or are people talking about how you go about making some kind of a broad national effort? Is that happening?

Mr. MOLL. The American Forestry Association is pushing for that, and will very soon be trying to initiate a national program that will help bring in all of our sort of citizen leaders into an effort, a national effort, to try to get these trees planted in the city.

What the Lawrence Building Laboratory is showing, what else is so interesting about that is we know the effect of the oasis effect that takes place. We know that we have heat islands where we are reporting the higher temperatures.

But in the Washington Post the other day they showed in Palm Springs the temperature has actually gone down because of all the golf courses and other green areas that they put in. This oasis-type effect actually sort of supercools those areas and keeps us then from producing all that CO_2.

The Lawrence Building Laboratory is showing that one urban tree is equal to about 15 rural trees as far as its job of global cooling, that the two sides of the equation, one, fixing CO_2 or carbon, and secondly in cooling so that we do not produce more on the other side.

So I think it is an interesting possibility, one which we think we have got a start on, but I think needs a lot of support and push. And we would appreciate any effort we could bet from up here.

Senator **Wirth**. We would like to talk to you about that. Dr. Dudek, how do you respond to Dr. Marland's comment on the conservation reserve and the fact that the land probably is not very productive land to begin with, water problems and the other items that Dr. Marland mentioned?

Dr. **Dudek**. First, I would note that the land has been sufficiently productive to be used in agricultural production.

Second, that according to Oak Ridge's own work, the single largest cost item in conversion to these forest systems is land preparation. In the case of converting lands from a Conservation Reserve Program into new forest areas, we forego this largest part of the cost involved.

The numbers I used also for fixation rates also come from the Department of Energy and Oak Ridge National Labs research work. They roughly involve something on the order of about a span of species, but most conservative of them is about 4 metric tons of carbon equivalent per year. That gives about 11.1 million acres of land.

Remember again that these are strung out over roughly a period of a decade. We are only talking about adding roughly a million acres a year over that period, and we are only talking about doubling the current goals for conversion of retired agricultural land into a forested component.

There is already existing legislative intent to expand the Conservation Reserve Program by approximately 50 percent. It seems to me that by piggybacking several existing public policy objectives, we can really maximize the public benefit from these programs.

Senator **Wirth**. Just a final question. Have you discussed this with a variety of people in the private sector about their interest in doing this, trying to put this in legislative form and where you go from here with it?

Dr. **Dudek**. In fact, there is some existing interest in the private sector concerning the possibility of offsetting CO_2 emissions.

I believe that there have been some proposals that have been evaluated, particularly with respect to using the debt leveraging possibilities in less-developed countries, and that this would be an extension of this same kind of idea.

In terms of actual implementation, I think that the Federal agencies could clearly play a role in providing expertise and guidance, technical guidance, to states both with respect to certifying the kinds of CO_2 offset programs that would be eligible as well as in providing a conduit for the existing contractual arrangements between agricultural private landowners and individual utilities.

There is some precedent for this. The U.S. Fish and Wildlife Service piggybacks on the CRP with an additional $5 per acre payment for waterfall management purposes, which essentially allows them land access. This is targeted, of course, in the prairie potholes region of the Western United States.

Senator **Wirth**. A final comment on that. As was talked about, looking at timber taken off Federal land and putting some kind of surcharge on that, the user fee on that, for the purpose of looking at reforestation and the kind of long-term research that we ought to be doing and so on.

In fact Dr. Robertson was saying that this requires significant investment, and there are a variety of other reforestation programs we ought to pursue. Presumably we ought to consider the possibility of a user fee that goes with that.

We have user fees for a lot of other things, why not forest land? Do you have any thoughts on that?

Dr. **Dudek**. I think that one of the main obstacles, both to programs like expanding the Conservation Reserve Program or getting it, getting the amount of forested acreage under that program increased, it is clearly the issue of program cost.

To the extent that we have new revenue sources geared to interest sectors of the economy intimately involved in these problems, I think they provide additional benefit in addressing this serious issue.

Senator **Wirth**. Senator Evans.

Senator **Evans**. Thank you, Mr. Chairman. Let me start, whoever can answer this. I suspect we could start with Dr. Marland.

Can you tell us roughly what are the relative contributions to CO_2 emissions amongst forest fires, automobiles, fossil fuel plants, human breathing? Who contributes the most? What are the relative elements?

Dr. **Marland**. These are numbers done by Meyer Steinberg at Brookhaven National Laboratory. He calculated by end-use.

His number is 31—this is just for the United States—31 percent from electric utilities, 28 percent from transportation, 22.5 percent from industrial uses of fuel, 11 percent from residential uses of fuel, 7 percent from commercial.

Human respiration is a quick recycle, and so that really is not a net contribution. If we were to add in forest fires, you are talking something, on an annual average, something on the order of 3 percent, I would say.

Senator **Evans**. Those add up to about 100 percent of contribution, anything else is minor, or not terribly important?

Dr. **Marland**. Cement is a minor contribution.

Senator **Evans**. Cement is, I suppose, really an industrial manufacturing process, is it not?

Dr. **Marland**. Well, it is not fuel-related though. It is inherent in the cement manufacture process. That has nothing to do with their consumption of fuel. These numbers are all fuel-related.

Senator **Evans**. So you are not talking about the kiln elements of cement production?

Dr. **Marland**. I am talking about burning of the limestone, the carbon dioxide that comes off the limestone itself. But it is, again, it is a 2 percent contribution.

Senator **Evans**. OK. In your paper on page two, you talk about the differences.

You say, second, for maximum sustained yield, the average standing biomass is approximately one-third that of mature forests. In other words, there is an explicit tradeoff between maximum carbon storage and the maximum rate of carbon uptake.

Where is that tradeoff? You say the average standing biomass is approximately one-third that of mature forests, in terms of carbon storage. But are we interested in carbon storage or in the speed with which the forest takes up new carbon?

Dr. **Marland**. I think that is an excellent question. It all comes down to, what are we going to do with the carbon once it gets into the tree? If we are going to recycle it as fuel wood, then I think the continuous recycle is fine.

But if it does not replace fossil fuels, then going from a mature forest to a rapid recycle forest does not gain you anything. In fact, it stores less carbon in the biosphere.

Somehow, of course, we would like to maximize both the uptake and the storage. It just does not work that way.

Senator **Evans**. Well you say it stores less carbon than the biosphere.

But if you have a mature forest which has the most carbon per acre presumably in it, if you cut it down and saw it into wood, and do not burn any of it, then that carbon stays stored presumably. It is not released to the atmosphere.

Dr. **Marland**. Correct.

Senator **Evans**. So is that less productive in terms of what we are trying to get at than a rapidly growing forest that is absorbing more carbon at the time? And I know you have to go through the whole cycle of trees.

But presumably cutting, replanting, reforesting on a cycle over a long period of time would absorb more carbon, assuming that the wood harvested for the most part would remain in a form that would not release the carbon, then would you not want to harvest and regrow forest rather than just allow them all to grow to maturity and slow down in their carbon-absorbing capacity?

Dr. **Marland**. As long as we are doing something useful with the wood, you are right. We would be better off to continually take it out of the atmosphere and do something with that wood.

Senator **Wirth**. What do you do with the wood?

Senator **Evans**. Build houses.

Senator **Wirth**. There are only so many houses that can be built or so much timber that gets cut. What do you do if you have a process of growing a lot of forest, as we are suggesting, you have got—and you do not burn the wood or use that as an alternative fuel, it builds up somewhere.

I mean, what do you do with that wood? You have to use it, essentially to do a lot of this you really have to use it as fuel, do you not?

Dr. **Marland.** You either have to use it as a fuel or someplace that it ends up in long-term storage. I do not know what the economics are.

You know, this is one of the few places in the world where you come in and the people have got really wooden desks and wooden chairs. In my office everything is plastic. You know, we are making everything out of crude oil anymore. And it gets to be crazy.

Obviously, there are economics that are involved. It is cheaper to make a desk out of plastic than it is out of wood.

Senator **Evans.** We could figure out a way to change those economics. We do it all the time here with taxation.

Dr. **Marland.** I do not know how many desks and houses you make out of wood, but that is wood that is tucked away somewhere.

Even, you know, you make paper. You take all this stuff, and if you burn the paper in the incinerator then the CO_2 goes back in the atmosphere. And if you landfill the stuff, then it is hidden away somewhere.

Senator **Wirth.** That is my question, if I can just interrupt.

If you have a cycle of a forest, and I am not yet clear on the carbon cycle, the forest grows and burns, the carbon goes up into the atmosphere. Right?

So the only thing you gain out of a lot of forestation is to have the forest not burn, to have it stay in some kind of a form that retains the carbon. Right?

Dr. **Marland.** Right.

Senator **Wirth.** So you make a lot of houses and a lot of desks and a lot of chairs. And I am not being facetious. I am just trying to think, where does this all go? What happens to the carbon? What happens to the forest?

Senator **Evans.** That is presumably what we are doing with all the trees we have got now.

Dr. **Marland.** A mature forest, the Pacific Northwest, it just sits there and it has got a lot of carbon locked up in it. But it is taking up carbon at a very minor rate.

If you simply destroy that forest and make it an agricultural land, you put all the carbon dioxide into the atmosphere. But if you use it to recycle wood and build wood products, or use it for fuel to replace coal, all of these things help reduce net carbon emissions.

Senator **Evans.** So there are really two things, one is to use it for products that will retain the carbon in storage, or substitute it for other contributors to fuel.

Dr. **Marland.** Substitute for fossil fuels. The tree is cycling carbon, the fossil fuel is taking carbon out of the ground and putting in anew into the atmosphere.

Senator **Wirth.** How efficient is the substitution of wood for other fossil fuels?

Dr. **Marland.** That is not my field. Sorry. Not good, I think. You get a whole host of other problems.

Senator **Evans.** It depends upon what you put in the economic equation, I suppose, and whether the costs ultimately, the environmental costs to all of us of global warming falls within that equation. And you could change the economics pretty fast.

Senator WIRTH. I guess there is no question that somewhere in the this mix, if we think in terms of the increments on global warming, you have got a little bit here, a little bit there and a little bit there and add them all up and we can have an impact, there is something in the area of forestation, reforestation, that we want to get into.

Dr. MARLAND. It is also complex. Everything wraps back around. I mean, I read this S. 2776, or whatever it is called, and my reaction was, without evaluating each piece, all the right elements are there and how do you bring them together and what are the details. You end up with renewable fuels and reforestation and conservation.

All those things are the right kinds of things to be talking about. But I think that we are a long way from melding them all together and finding out what is the most economic way to wrap it up to address the total problem, and all the attendant problems that come with it.

Senator EVANS. Dr. Dudek has suggested the idea of requiring some kind of planting contribution of that or a similar sort when building a new fossil fuel plant.

What about the practicality of that? It may be done in a way that says to a new power plant producer, the requirements for fossil fuel emission are X. A very, very, maybe barely attainable with high expense, but the maximum degree to which you can reduce those through scrubbers and other kinds of devices.

Or as an alternative, we will allow you to contribute a little more, if you turn around and provide and maintain the kind of forest contribution that will eat up that much or more.

Sort of an incentive program that says you have got to do one thing which may cost you a lot of money, or if you want to forego some of that contribute by acquiring, holding and producing the kinds of trees that will use up an equivalent amount.

Dr. MARLAND. You have to be careful—I guess we all realize. I mean, if you burn coal you get carbon dioxide. It just simply is not one of the choices. You can collect it, but what do you do with it if you collect it?

It is not cheap to collect it, of course, to begin with. But you get out the carbon and then what? The easiest "what" is to put it into trees. But as I said, a 1,000-megawatt plant, and this is a very fast-growing plantation, we are talking about a 15 mile radius of trees, and that is a lot of trees.

As Dr. Dudek has pointed out, there is a proposal now from a company in the United States, they are going to establish an offset program. I think that is moving forward, but they are going to build a power plant and burn coal in Texas, and they are offering money to some tropical country to do the offset. It is kind of a neat idea.

Senator EVANS. But it is possible, though, is it not, that when you say it is tough to collect the carbon you can collect it and fix it chemically into a relatively inert substance, I suppose?

Dr. MARLAND. There really are not any good options that way. The things that have been talked about are putting it into salt mines, abandoned gas wells, or putting it into the deep ocean, and hope the ecological impacts are not too severe.

Senator **EVANS**. Can you not chemically combine it to create other compounds?

Dr. **MARLAND**. I have not heard a reasonable suggestion in that vein.

Senator **EVANS**. You mean it could be done but not practically?

Dr. **MARLAND**. Yes.

Senator **EVANS**. Mr. Moll, I ran into an interesting equivalent of your proposal for urban trees, not necessarily urban trees but certainly a massive tree-planting program.

When I first went to China in 1974 I was struck by the number of trees alongside the road, not just one row on each side but several rows on each side. And thought we were being herded down the one grand highway from the highway into town, but found as we traveled and as we flew over the country that these were repeated everywhere.

We were told when we asked that Chairman Mao said, plant trees. When you get a billion Chinese planting trees, you have got a heck of a lot of trees planted, and a very successful program.

I do not know what you do in the Northwest, however, where our problem is not so much planting trees around the houses to help the air conditioning quality but cutting away the trees to let the sunshine in.

Mr. **MOLL**. The deciduous trees, though, can help both, because they lose their leaves and they do block the wind. And so it is not as significant. But there is definite benefits.

Senator **EVANS**. Are deciduous trees more effective in their carbon dioxide absorption than evergreens?

Mr. **MOLL**. I can't answer that.

Senator **EVANS**. Dr. Marland, do you know?

Mr. **MOLL**. It mostly depends on size, I believe, and how fast they grow.

Senator **EVANS**. Is there any inherent difference in the two types of trees?

Dr. **MARLAND**. There is not an inherent difference. No.

Senator **EVANS**. So it is more a function of their age and their place, at least, in the growth cycle of that particular tree?

Mr. **MOLL**. Right.

Senator **EVANS**. You say the urban trees have a greater consequence than trees planted in a rural area for the cooling effect that they provide, presumably then lowering the need for air conditioning and the use of fossil fuels for electrical production to run the air conditioning plants. Is that essentially it?

Mr. **MOLL**. Yes. There are two, they measure two different ways as far as savings, and they call them indirect and direct.

One being the actual shading of the house, that being the direct. And the indirect being how much it saves at the power plant. Or by how much you need to produce. Because it is hotter out. And then of course you get the third savings by fixing the carbon in the same way. So it is an interesting setup.

Senator **EVANS**. But the trees will contribute in a positive way during the heat of summer insofar as the indirect air-conditioning costs but not in the negative way necessarily in the wintertime.

In fact, is it a positive or a negative in the wintertime?

Mr. MOLL. It is a positive in both. It is a positive effect because they do have a warming, both from wind, and just the fact that they are there and they are living. They have certain heat that they give off.

Senator EVANS. Dr. Dudek, you talked about the offsets for new power plants in the transfer of agricultural lands.

It seems to me that there are some problems, I do not know whether you have examined this. But in our part of the country, there are a good many marginal agricultural lands that they generally get planted from fencepost to fencepost because of governmental programs, which encourage them to plant more.

No matter how the governmental programs are couched, farmers are smart enough and fast enough to figure out ways to maximize their income under whatever program it is. A lot of that included bringing in these marginal lands.

To now remove them from production for the growth of trees does not sound to me too practical. In some of our wheatlands in eastern Washington, they have been under wheat, dryland wheat management for the better part of 100 years. But in the hundred years preceding that they did not grow any trees either. They were essentially grasslands and not treelands.

How practical is it to attempt to push trees into an area that has not shown itself very hospitable to trees for a long time?

Dr. DUDEK. I quite agree, Senator, that is not a highly practical idea. The State of Washington was not one on the list of states proposing to construct fossil fuel-fired facilities over the decade involved. Consequently, it was not involved in the calculations or in that particular proposal.

Senator EVANS. I understand. But does it not make sense, instead of on a state-by-state basis, if this is a national problem and there is an offset concept, there is nothing to prevent a power plant in Texas from seeing to it that trees are grown in Washington or someplace else. It does not have to be right around the power plant.

Dr. DUDEK. No. That is absolutely correct. And I would further add to that that the total number of acres of land in the agricultural base, estimated by the USDA to be highly-erodable, is something on the order of about 173 million acres.

Of that, about 100 million have been targeted for treatment under both the Conservation Reserve and Conservation Compliance Program. And so I think that there is more than adequate acreage to find 10 million acres to put into new forest.

Senator EVANS. Would all of that 100 million, however, even be potentially good land for timber production or tree production, rather than whatever agriculture it was engaged in?

Dr. DUDEK. Much of the land that is involved in these resource inventories is in the Midwestern part of the United States.

It is exactly this area that has been targeted by the Department of Energy in its evaluation of biomass potential for energy, renewable energy resource. It is for those reasons, and for the availability of that marginal land, that they have been identified.

Senator **Evans**. In your paper, on page six, you have four different tree varieties that are delineated. Silver maple, black locust, eucalyptus and sycamore.

Are those just samples of what kinds of trees you may use? Or are they particularly productive samples? Or what?

Dr. **Dudek**. These were trees that were involved in evaluation for their biomass potential as a part of the long-run short rotation research program that the Department of Energy has at Oak Ridge.

They span a range of productivity estimates. The silver maples are down at the low end. The eucaplyptus are by far the fastest-growing of those. It was used to show the differences in program costs and area involved, as a function of productivity.

I think the point that both Dr. Marland, as well as Mr. Robertson, made concerning the importance of productivity changes in efficiency of sequestering carbon dioxide from the atmosphere.

Senator **Evans**. You sequester the carbon dioxide with those efficient-growing trees. You know, we are going to be up to our hips in black locust and sycamore and eucalyptus, and you can only feed so many koala bears with eucalyptus leaves.

What do you do with all of that? Once they have become mature forests and have soaked up all the carbon and are not soaking up much any more, then what?

Dr. **Dudek**. I think the main point of such a policy is, as has been identified earlier, is one of an interim policy. The evaluation is over roughly a 50-year time period.

It has been this same time period recently identified as by approximately 400 scientists convening in a world hemispheric conference in Toronto as the approximate amount of time that we have to change the way we do business with respect to fossil fuels.

In particular, in S. 2667, we have an objective of reducing CO_2 emissions by about 20 percent. The estimates are that to stabilize atmospheric concentrations of carbon dioxide, we need cuts on the order of about 50 percent.

I think the point to this policy is to begin to move down that path.

Senator **Evans**. In that 50 years, what are we going to do, however? I see this very interesting 11-country sample of Dr. Marland.

U.S.A. on a per capita basis emits 5 tons of carbon per person, the U.S.S.R. 3.6, China one-half of a ton per person. In 50 years we may have cut ours in half. But can we expect China to stay anywhere near a half per person, when they are moving as rapidly as they can with the goal of becoming an industrialized nation?

If we are good enough to get down from five to two and a half, is there any reason to expect that they should be any lower than that?

Dr. **Dudek**. No. In fact, I think we can look to the recent Montreal agreement there for some precedent, where in fact the developed nations of the world were involved in making commensurately larger cuts in their loss of chlorofluorocarbons with some hiatus as well as technology transfer offered as inducements for participation by the less-developed countries.

I think it is precisely the point that the developed world needs to show both its resolve as well as environmental leadership in this arena, if we expect to craft an international agreement.

Senator **Evans**. It seems to me that the ratios, however, are extraordinary. And it poses the worldwide problem, we are talking about a worldwide environmental concern and not just a national concern.

But if you take a country of 250 million people and cut their five in half, and compare that with a country of over a billion people who may have five times as much as they do today, the imbalance is extraordinary.

We will not be anywhere near a balance, we will not be anywhere near the levels we are at today, unless we do a lot more massive job than that.

I do not know if anybody has tried to do the figures or whether you, Dr. Marland, have looked at that in terms of how much the industrialized countries would have to come down on a per capita basis to allow the less industrialized countries to have some reasonable rate of industrialization, which they are all determined to do.

To keep us even close to balance, are we not in a whole lot bigger problem? An idea that we can cut ours in half in 50 years, is that going to keep us anywhere near close to balance? Or are we going to be a lot worse off worldwide than we are today, if that is all we do?

Dr. **Marland**. Well, I think you have said it very well. It is a global problem.

The United States, although we are way up there on a per capita basis, we are a small fraction of the total people. What programs are adopted in the United States are not going to have much impact unless they have much broader application.

Senator **Evans**. Well, that is right. We have fewer people, but the total emissions which you have here in CO_2 is almost two and a half times that of China. Even though we have a lot smaller population. If I am reading the figures right.

It is almost 10 times as much as India, even though we have one-third the population.

Dr. **Marland**. That is correct.

Senator **Evans**. So when you start generating those huge populations times any kind of industrial output growth, that of necessity creates some carbon dioxide or CO_2 emissions.

It just seems to me that the kind of goals we are talking about with the total amount, and not on a per capita basis but the total amounts that we are putting out is a lot tougher problem than anyone has posed so far. A lot tougher problem to keep even at current levels worldwide, levels of emissions.

Dr. **Marland**. The data show quite clearly that the U.S. share has been shrinking, that over the last decade the U.S. contribution has been, in total mass, really quite constant, whereas many other portions of the world are continuing to increase in emissions.

Senator **Evans**. But is it not hopeless—I guess that is the word I want—hopeless to predict that we will be able to maintain our level of industrialization and standard of living, all of which contributes to the CO_2 production and tell all the other nations, sorry, we have got ours but you have got to keep your tropical forests up, you have got to cease industrializing, you cannot have any more automobiles, you have got to quit using fossil fuels in your power plants? How fast are they going to listen to that?

Dr. **Marland**. One of the interesting columns in this table is the fossil fuel emissions per area of closed forest. I did the calculation. If each country were to be obligated for its own CO_2 emissions, if we had to take ours and Zaire had to take theirs and West Germany had to take theirs, obviously the folks in Zaire can handle their own. The folks in West Germany and us have got big problems.

Can we call on the Third World countries to cover for our CO_2? That does not seem reasonable to me.

Senator **Evans**. They might do it for a price. The price would be pretty high, I would suggest. Thank you, Mr. Chairman.

Senator **Wirth**. Senator Evans, thank you very much. And gentlemen, we really appreciate you being here for a long afternoon. And again, the record will remain open for any comments that you might like to make.

Mr. Moll, we look forward to hearing from you and your thoughts as to what kind of steps we want to take. Dr. Dudek, any legislative specifics in taking into account some of the comments that Dr. Marland made as well.

Gentlemen, thank you very much. We appreciate you being here.

[Whereupon, at 4:30 p.m., the hearing was recessed, to recovene Tuesday, September 20, 1988.]

NATIONAL ENERGY POLICY ACT OF 1988 AND GLOBAL WARMING

TUESDAY, SEPTEMBER 20, 1988

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 9:03 a.m., in room SD-366, Dirksen Senate Office Building, Hon. Timothy E. Wirth presiding.

OPENING STATEMENT OF HON. TIMOTHY E. WIRTH, U.S. SENATOR FROM COLORADO

Senator WIRTH. Good morning. The committee will come to order.

Yesterday the committee received very useful testimony about the implications of global warming for forests in the United States. The Chief of the Forest Service testified that we have reason to be concerned about the implications of global warming and climate change for our forest systems. Rapid climate change, they noted, could outpace the ability of forest ecosystems to adapt to rapid changes in temperature. We have a significant job ahead of us to better understand what a warmer future might have in store for forested areas. The Forest Service has showed leadership in beginning to develop a research program along these lines.

We also were told that efforts to increase the area and productivity of the world's forested areas can play a role in slowing down the rising atmospheric concentrations of carbon dioxide, the primary greenhouse gas. Plants and trees consume vast amounts of carbon dioxide in the process of photosynthesis. This natural sink for carbon dioxide could be enlarged through a strategy of regeneration and enlargement of forested lands.

But we cannot begin to embark on such a strategy until we turn around current trends toward losses in the tropical forests. Alarming amounts of forested land in the tropics are being cleared in short-sighted development schemes. Deforestation is running at a clip of about 27 million acres a year in the tropics, and recent monitoring by NASA in Brazil's Amazon basin indicates that even those estimates may be understated.

What does the loss of 27 million acres a year mean for atmospheric loading of carbon dioxide? The numbers are staggering. Scientists estimate that the carbon dioxide emanating from downed forests in the tropics accounts for at least 20 percent of worldwide emissions, more than 1 billion tons per year.

How can we turn this around, stabilize the world's forests and begin the process of reforestation? For the past several years, a great deal of attention has been given to addressing the root causes of tropical deforestation, but still devastation continues at an increasingly alarming rate.

Despite the development of the tropical forest action plan and environmental initiatives within the World Bank and other multilateral lending institutions, we are still faced with an enormous task. Progress needs to be made in the development policies of donor nations and at bilateral and multilateral development institutions.

One of our most fundamental goals must be to manage the magnitude of the development task by addressing the issue of population growth. The challenges of economic development and increased standards of living in developing nations are compounded by swelling populations and the accompanying problems of urban crowding and rural landlessness.

To address these problems, we have to develop creative strategies that give developing nations the tools that they need to get a handle on population growth and create sustainable and diverse economies. It is a formidable challenge. But, it is a task that must be achieved if we are to address the growing concern about global warming and climate change.

The committee looks forward to receiving the insights of today's witnesses on how we can address these issues.

[The prepared statement of Senator Johnston follows:]

Statement by the Honorable J. Bennett Johnston
September 20, 1988

I am pleased to welcome you to this morning's hearing on international deforestation and sustainable development's relationship to global atmospheric change.

The rainforests have existed largely undisturbed for millions of years and yet man, in his shortsightedness threatens their continued survival. Last year we lost precious tropical forest resources equal in size to the state of Indiana; figures for this year's acreage lost to deforestation are expected to be equally grim. Although developing countries currently contribute only a small percentage of carbon dioxide in the form of fossil fuel emissions, their contribution to atmospheric change through the destruction of the earth's tropical forests is considerable.

Scientists believe that a full fourth of total carbon dioxide emissions come from the burning of forests to provide land for agricultural and ranching uses. The burning not only contributes to atmospheric carbon levels but eliminates an important "sink" for carbon dioxide from fossil fuel emissions. In addition, the loss of forests in the tropics may have important implications for global weather patterns , storm surges, and fresh water supplies.

The United States is responsible for almost a fifth of all greenhouse gas emissions and we must act to reduce them, yet our nation cannot solve the global warming problem unilaterally. We must work in tandem with other nations and multilateral agencies to fashion energy and environmental policies that go beyond short term solutions. However, devising energy and environmental protection strategies for Third World countries that take into account rapidly expanding economies and populations is not an easy task. How do you convince newly developing countries to forego economic and industrial expansion that developed nations already enjoy in the interests of a future global environmental threat

The secret lies in helping nations to fully realize the global implications of climate change; sea level rise and increased runoff and silt from deforestation exacerbate flooding in Bangladesh, storm surges in the Philippines, and droughts in the Sahara. The World Bank and the United Nations organizations have the ability to provide financial incentives for developing nations to cooperate in such policies as reforestation and sustainable development. We must seek to ensure that Third World development funded by industrialized nations is not wreaking havoc on the world's environment.

More importantly, the industrialized nations must match concerted Third World efforts with energy conservation and sustained resource management policies of their own. It is only through the continued cooperative efforts of nations to reduce carbon dioxide and trace gas emissions and control deforestation, that we can hope to make any progress in controlling global atmospheric change.

Senator **Wirth**. We have a very distinguished panel this morning, and we are going to begin, if we might, with Dr. Lester Brown, the Project Director of Worldwatch here in Washington; and to be followed by Mr. Richard Bissell, the Assistant Administrator, the Bureau for Program and Policy Coordination for A.I.D.; then Dr. Robert McNeal, Manager of Tropospheric Chemistry Program for the Earth Sciences and Applications Division of NASA. Gentlemen, we thank you very much for being here. We will then move to Dr. Repetto, Mr. Breck, and Dr. Wirth.

Dr. Brown, if you could start us off this morning, and we would appreciate that. You all are familiar with the rules of the committee in which we will include your statements in full in the record, and we will then leave the record open for a couple of weeks for any further comments you may want to make or for questions from other members of the committee. Why don't we proceed from there? If you would summarize your testimony in whatever way you think would be most useful. Thank you, Dr. Brown.

STATEMENT OF DR. LESTER BROWN, PROJECT DIRECTOR, WORLDWATCH INSTITUTE

Dr. **Brown**. Thank you, Mr. Chairman.

First, two comments on the legislation. I think you are to be commended on the breadth of this legislation. It is the kind of thinking that we now need to be doing as we look at what is happening to the planet. It not only is a useful piece and important piece of legislation, but it also has already played an important role in public education in raising the level of public awareness and understanding through the testimony that you have been having in recent months. And that is an important part of the process. Until the public understands these issues, it will be almost impossible to get any effective policy response.

Senator **Wirth**. I must say, Dr. Brown, one of the challenges we face is to continue public awareness and concern when it gets cooler and then gets colder in the winter.

Dr. **Brown**. We may have some other things happening like rising food prices and holes in the ozone layer and things to sort of keep the issues alive in the months ahead.

I would like to make four general points about the legislation. The first is that this bill, which is focused on climate stability, is really about social stability. We are talking not just about changes in climate; we are talking about the social stability of the planet. Let me illustrate by using food as an example.

At the beginning of 1987, less than 2 years ago, we had 101 days' worth of grain consumption in storage as carryover stocks. When we begin the next harvest, we estimate that will be down to 54 days. That is lower even than it was in 1972–1973 when world grain prices doubled. It may be the lowest level since the years immediately following World War II.

Now, this is not a planned reduction though we have been holding some land out of production. What we have seen in the last 2 years is, one, a monsoon failure in India last year, and then this year drought-reduced harvests in the United States, Canada and

China, important in the United States and China because these are the worlds' two leading food producing countries.

In the United States, by many indicators, this drought was the most severe on record. This year for the first time possibly ever grain production in the United States will be below grain consumption for this year. USDA now estimates the harvest of 190 million tons and our consumption this coming year at 202 million tons. Now, that doesn't pose a serious problem for us because we came into this year with very substantial carryover stocks, so we can fill that deficit simply by consuming our reserves.

But we also export about 100 million tons of grain out of a 300 million ton typical harvest, and there are roughly 100 countries that depend on us for grain. We are going to be able to satisfy those commitments this year by exporting our reserves. But when this year ends—that is, when the next harvest begins—there won't be very much left in grain stocks in this country or anywhere else in the world. We will be basically down to pipeline reserves.

Then the question becomes what happens if we have another drought in 1989 comparable to that in 1988. That question was raised when USDA released its August crop report, and the response was that would create a situation that would be "catastrophic."

Then the question is what are the odds that we could have another drought-reduced harvest on this scale or approaching it. And the answer is we don't really know. We know that in the past that severe droughts have come in clusters, but it is very rare to have back-to-back severe droughts. But then again, we have never been in a warming situation of the sort that we are apparently in now.

The three most serious drought reductions in the U.S. grain harvest since 1950 have all occurred in the 1980's, 1980, 1983 and 1988. Those three drought-reduced harvests happen to have occurred during the five years that NASA reports as the five warmest years in the past century, those 5 years being 1980, 1981, 1983, 1987 and almost certainly 1988.

Maybe this is just a coincidence. There is no way that we can conclusively link these droughts to the warming. But it is clear that the warming and the possibility of this linkage is creating a great deal of uncertainty. We now face a far wider range of uncertainty in terms of future harvests than at any time in the past.

As we look ahead at 1989, there are two options. The two sort of extremes are, one, we could have the best harvest we have ever had. That is a distinct possibility. We could also have another drought-reduced harvest like 1988. We know that 1988 was warmer than 1987. What if 1989, in turn, is warmer than 1988? Then the chances of that increase.

If we were to have a drought-reduced harvest with most of our stocks depleted, then there would be the prospect of soaring grain prices, and this is a far more destabilizing factor in developing countries than it is here. When we buy a loaf of bread for a dollar, it contains roughly a nickel's worth of wheat. If the price of wheat doubles, then the price of the bread goes to $1.05. In reality with some markups, it will go a bit further than that.

But the point is the increase in the price of wheat doesn't have a great effect on our ability to purchase enough food. But in developing countries where people buy grain as grain, whether it is wheat or rice or corn, if the price doubles, then many of them are forced into not only a difficult, but an impossible situation in many cases. They have to tighten their belts, and there simply aren't any notches left. They are already spending most of their income on food. If the price doubles, there is no way they can adjust.

If—and I emphasize the if—we should have another drought-reduced harvest in this country next year, then the shock, the global economic shock, could well rival that of the oil price increases of the 1970's. Oil is an intermediate product. We don't eat oil, but we do eat grain. And the effect on consumers would be very direct and immediate.

I think among the indicators that we will be watching over the next several months are things like winter snowfall, moisture levels in the cornbelt and in the Great Plains. Indeed, there is an article in the Times this morning looking at specifically this question because as the extent of world stock depletion becomes clear, our dependence on the decent harvest next year will also become clear.

I would repeat this first point again, namely, that S. 2667 deals with more than climate stability; it deals with social stability and economic stability.

The second point I would make is that in talking about stabilizing climate and trying to reestablish a carbon balance in the atmosphere, we are really talking about a fundamental restructuring of the global economy. We are not talking about a few adjustments here and there. We are not talking about fine-tuning. We are talking about fundamental restructuring.

I used food as an example a minute ago. Let me use transportation as an example here.

We have grown up, those of us in this country, in an automobile-centered industrial economy. Not our transportation, but our whole industrial complex has been centered heavily around the automobile and the supporting services. During our lifetimes we have seen the automobile-centered economy become a goal of virtually all societies throughout the world. The assumption used to be that some day all countries virtually would have an automobile-centered economy as we have.

It is now becoming clear that that is not going to be the case. We first began to realize that in 1973. We realized there wouldn't be enough oil for the world to have automobiles as we do. And then in recent years with the economic downturn in places like Latin America, we have begun to realize that there wouldn't be enough affluence to own automobiles. Now, as your legislation makes clear, we are looking at climate change, the possibility that the effort to preserve the habitability of the planet is also going to limit the use of fossil fuel powered vehicles in the future.

In some countries we are already seeing these forces beginning to take shape and to restructure transportation systems. In the last issue of our Worldwatch magazine we had an article on the bicycle and the role it is playing in the world. There has been an enormous surge in the production and the use of automobiles in the last decade and a half, not so much in this country, but in many other countries in the world. Last year bicycle production totaled 105 million mostly for personal transport, not for recreational purposes. Automobile production totaled 33 million. The world bicycle fleet is now 800 million; the auto fleet nearly 400 million.

It is probably true now that more people commute to work by bicycle than by automobile. That would not have been the case 20 years ago mostly because of the rise in affluence in China and the growing middle class in India. People are turning to bicycles. They cannot afford cars, and the world can probably not afford for them to have cars.

But it seems clear to us, in looking at both the environmental and economic influences that are shaping the future, that the transport vehicle of the future has two wheels and not four. The bicycle is responsive to almost every important environmental problem that we face whether it is acid rain, air pollution, climate change. You name it. What we have to begin thinking about is how to create an environment where we can use the bicycle more effectively, an environment that is hospitable to the bicycle rather than hostile. I cite this as simply one example of how we are going to have to rethink the future as we begin to take into account the need to reestablish a carbon balance.

A third point—and this is a broader one responding to many of the issues that the legislation deals with. It looks to us as though the human prospect, the human future, depends very much on three things: planning families, planting trees and reducing fossil fuel use. Planning families, planting trees and reducing fossil fuel use. You deal with all of these in the legislation. However difficult it may appear to do some of these things—and it is certainly not going to be easy—there are national success stories in each case. Let me cite population stabilization.

There are 13 countries in Europe which have now stabilized their populations. They have reached zero population growth. Births and deaths are in balance; no appreciable increase or decrease in population size.

I would also cite in this area the progress made in China over the last decade in getting to break some population growth. The Chinese have been willing to do what many third world governments have not been willing to do, and that is to face the reality of population growth and its threat to the future.

The second activity that I mentioned, which is planting trees—there is one country that has been very successful in increasing the forested area over the last decade and a half, and that is South Korea. South Korea, beginning in the early 1970's, decided to launch a national reforestation effort. They have been eminently successful, have increased the forested area. Many of the hillsides in South Korea that were once denuded are now covered with trees. South Korea has added to its forested area an area about two-thirds the area in rice, a major achievement. It is the model to which other countries can look in attempting to increase the forested area and not only reduce CO_2 emissions, but actually begin storing some of the excess carbon dioxide in the atmosphere.

I also mentioned the need to reduce fossil fuel use. And again, we have some success stories here. One is energy efficiency which clearly has to be at the top of the list, and one can come up with a long list of steps to increase energy efficiency. Japan is clearly a success story.

We are using nearly twice as much energy to produce a dollar's worth of GNP as Japan. The Soviet Union is using three times as much as Japan. If the world were to take the Japanese level of energy efficiency, which is far from state of the art, and were to move toward it, we would reduce global carbon emissions from fossil fuels by probably close to two-fifths. That wouldn't require any new technologies at all. They are all there.

The other point is renewable energy. There are two countries with substantial industrial sectors that made it into the renewable energy era. Those two countries, very different, are Norway and Brazil. Norway is now getting 60 percent of its total energy supply from renewable sources, mostly hydropower but to some degree, forest products. It is sort of ironic it is an oil exporter.

The second country is Brazil. Brazil is using a combination of hydropower, alcohol fuels and wood to get 59 percent of its total energy from renewable sources.

Now, we have focused attention, quite rightly, on the deforestation of the Amazon, but most of that is not for firewood. That is just burning to get rid of it. But the steel industry in Brazil, which is I think eighth largest in the world now, does about 40 percent of its smelting with charcoal from eucalyptus plantations. You can smelt steel with charcoal as well as coal. The Brazilians, because they don't have much coal, have chosen charcoal.

The final point that I would make is that I don't think we can over-emphasize the urgency of action on the issues that are listed in this bill. I think the next several years—in fact, if we don't get these trends turned around in the 1990's, then I think the world is in serious trouble, and the habitability of the planet will be coming into question.

We are seeing environmental deterioration now begin to have economic effects: Bangladesh losing a third—some say a half—of its summer rice crop from the enormous flooding, part of that due to deforestation; cropland in Africa, productivity declining in many countries in absolute terms despite advances in technology because of soil erosion and land degradation; forests in Europe losing their productivity because of damage from acid rain and air pollution; the North American grain harvest. Whether it was down this past year because of the warming or not, what did happen last year is what will happen as the warming progresses.

We are not talking entirely hypothetically now about declines in the human prospect about deterioration in living standards. Two continents, Africa and Latin America, will end this decade with lower living standards than those with which they began. The challenge is to not only trends around in these countries, but take the actions now that will ensure that other regions are not caught in this deteriorating environmental situation and deteriorating living conditions.

Thank you very much. And, again, I commend you on this legislation.

Senator WIRTH. Thank you very much for being with us, Dr. Brown.

Before you begin, Mr. Bissell, I might note for people who are standing in the back, there are a number of seats up here at the front. If you all want to come up and take one of those, please do so. Mr. Bissell.

STATEMENT OF RICHARD E. BISSELL, ASSISTANT ADMINISTRATOR, AGENCY FOR INTERNATIONAL DEVELOPMENT

Mr. **Bissell.** Thank you, Mr. Chairman. I appreciate the opportunity to testify this morning on behalf of A.I.D. on this very important and complicated issue of global warming. We at A.I.D. share your concern about global climate change and the effects on the prospects for sustainable, long-term development in the developing countries. This past summer seems to me has been a constant reminder of the possibilities of major changes in global climate patterns and has provided a sample of what the impact of those changes might be.

I have a written statement that I would like to have inserted in the record. Let me just itemize some points out of it for the interest of this committee.

The potential effects of global climate change such as sea level rise, changes in weather and rainfall patterns and the distribution of forests and productive agricultural lands are likely to have far more serious consequences for people living in the developing world than for us in the developed countries.

For example, in Bangladesh the severity of the monsoon floods in recent weeks has been increased by the growing destruction of the upland watersheds and higher than usual tides which appear to have slowed the rate at which flood waters flowed into the seas. Water now covers more than two-thirds of that country leaving approximately 30 million people homeless, and we are just beginning to get a full assessment of the damage.

Millions of tons of rice have been destroyed. Roads, power and telephone systems have been severely disrupted. Food supplies which are never adequate for Bangladesh are now almost nonexistent, and many health experts expect catastrophic health problems when the flood waters recede. Major outbreaks of cholera, respiratory disease, dysentery and other intestinal problems are feared at this point.

Developing countries which are already operating at the margin with barely adequate food, health care or shelter are not likely to be able to make the adjustments necessary to cope with major changes in agricultural patterns, forest cover, water resources and the quality of life. These countries simply don't have the financial, technical or natural resources to absorb the effects of such changes.

Higher levels of energy use explain the far greater contribution of the developed countries to global climate change. Statistics on carbon dioxide emissions from fossil fuels show that the United States alone contributes more than 25 percent of total emissions which arise primarily from fuels burned in motor vehicles and in the generation of electricity. Western Europe and Japan contribute about 23 percent with the Soviet Union and China contributing another 33 percent. Our estimate is that A.I.D.-assisted countries currently contribute about 6 percent of the total emissions, but with the economic expansion that we hope for in those countries, they will, in fact, account for an increasing share of global fossil fuel emissions.

A.I.D.-assisted countries, generally the poorest in the world, with per capita incomes ranging from $150 per person a year in Bangladesh, Mali and Burkina Faso, among others, to about $1,500 per year in Jordan, consume very little energy from fossil fuels. In countries assisted by A.I.D., each person has access for electricity consumption to only 50 watts, the size of one low wattage electric light bulb. In contrast, each citizen in the United States has access to approximately 3,000 watts of power.

Statistics on transportation also reflect the difference between developed and developing countries. In the United States we have 700 cars for each 1,000 people. In developing countries the figures are far lower: 9 per 1,000 in Sri Lanka, 11 per 1,000 in Botswana, and 19 per 1,000 in the Dominican Republic. This is significant since the transport sector in all countries is one of the largest energy consuming sectors and especially since it is the source of large amounts of carbon dioxide emissions, as well as other greenhouse gases.

The economic growth needed so badly by developing countries will undoubtedly require substantial increases in energy use. Even with significant increases in energy efficiency, energy consumption will probably need to increase at rates of 4½ to over 7 percent annually if real per capita incomes are to increase at even a minimal level of 2 percent, which is the target set by the World Bank. This would be far above the rate of increase in energy use occurring in the developed world. Many developed countries, including the United States, have actually reduced their levels of energy consumption at the same time that GNP has increased.

Twenty-five-year projections of energy use in A.I.D.-assisted countries suggest that even with increases in fossil energy consumption averaging 6 percent, which is based on a very optimistic view of economic growth, CO_2 emissions from all A.I.D.-assisted countries—all of them put together—would still be somewhat lower than the current emissions from the United States. That is over the next 25 years.

I don't mean by saying this to minimize the importance of these trends in the developing world, nor to suggest that developing countries should not be encouraged to reduce the rate of increase in their use of fossil fuels, but rather to suggest it is essential to the United States to assume a leadership role in this issue.

We need to begin to improve our scientific knowledge of these complex climate phenomena, the potential effects of these phenomena on agricultural productivity, forests and water resources in the United States and abroad, and of the technological options which could contribute to limiting emissions of greenhouse gases. Expanded cooperation with other countries and international agencies is also essential.

There are two areas that I would like to focus on for a few moments, that is, energy and forestry.

A.I.D. has worked closely with many developing countries to promote energy efficiency, to substitute renewable energy resources for fossil fuels, and to encourage the use of natural gas and improved power generation technologies, all of which help to reduce rates of increase in CO_2 emissions.

Activities in support of energy conservation and efficiency improvements have been an important part of the agency's energy portfolio since 1980. At that time A.I.D. recognized that the progress in energy efficiency made by the industrialized countries, in response to the rapid rise in worlds petroleum prices occurring in the 1970s, could also be made in developing countries.

Improvements in energy efficiency offer significant economic benefits especially important to A.I.D. countries which have very limited financial resources. Efficiency improvements reduce the need for new energy supply facilities, especially important in an era of scarce capital. In addition, such improvements reduce the rate of increase in carbon dioxide emissions as well as those of other gases.

A.I.D. has provided energy conservation assistance to over 20 countries. We currently have major in-country programs in Egypt, Morocco, Pakistan and the Philippines, and energy efficiency will be cornerstone of our expanding energy activities in India. A regional program under the auspices of the Association of South East Asian Nations, ASEAN, has provided important assistance to improve the energy efficiency of commercial buildings.

Two important activities which complement these technical assistance programs are our policy dialogue activities on energy pricing and our support for innovative approaches to electric utility planning. Energy price reform is clearly essential if energy efficiency improvements are to be sustainable. Such reforms also improve the financial viability of energy supply institutions and provide incentives for private sector investments in energy.

During the next year we will work with a small group of countries to begin developing least cost planning strategies for their electric utilities. Such models now gaining acceptance in the United States allow decision makers to compare the costs of alternative supply options including those from conventional fossil fuels, renewables and efficiency improvements. These planning strategies consider the usual financial costs as well as the environmental costs associated with various supply options.

Historically, A.I.D. has supported research and development efforts, demonstrations and full scale dissemination efforts involving a wide range of renewable energy technologies. Some of these have worked, frankly, and some have not. Current efforts focus largely on those technologies which have moved beyond the R&D stage and therefore can be competitive with conventional energy technologies.

For example, projects are underway to support biomass fueled power generation, using common agricultural crops and crop residues available in A.I.D. countries such as sugar cane, rice husks, and wood wastes. In terms of global warming, this of course is a neutral factor since decomposing biomass produces CO_2 as easily as when it is burned. But overall such fuels can reduce demand for additional fossil fuel. Biomass energy systems give economic value to waste products and reduce the need for fossil fuels.

It is our view that A.I.D.-assisted countries have to have increasing supplies of energy if they are to develop. Some of these supplies can come from improvements in energy efficiency and the increasing use of renewable resources. However, for the foreseeable future, there will still be a need to use fossil fuel resources.

A.I.D. can play a critical role in helping developing countries to use the most environmentally sound technologies and to make use of those energy resources that are the least environmentally harmful. Improvements in coal combustion technologies, in particular atmospheric fluidized bed combustion and integrated gasification combined cycle systems, offer superior technical and environmental performances.

In the forestry area, A.I.D. also supports a wide variety of efforts designed to reduce the rate of deforestation. These include activities to protect natural forests for sustained use, reforestation of degraded lands and agroforestry programs to improve agricultural yields. Research activities focused on improving multipurpose tree species hold great promise for strengthening reforestation.

During fiscal year 1987, the last year for which we have complete results, A.I.D. funded 146 forestry projects in 46 developing countries. The total life of project funding for these was almost $600 million.

Forests and other vegetative cover benefit the environment, as many people know, by producing oxygen, fixing carbon and modifying temperatures. In many tropical countries where we work and in some temperate countries as well, deforestation is occurring at an increasing rate and response to the pressures of populations on marginal lands, the clearing of land for agriculture and cattle grazing, increased timber production and demands for fuel wood. The proportion of increased atmospheric CO_2 attributed to deforestation is now estimated at 25 percent adding significantly to the level of CO_2 arising from the burning of fossil fuels.

The extensive burning of Brazilian forests and the fires in Yellowstone Park and other parts of the west clearly add significantly to CO_2 levels, although it is important to recognize that Yellowstone's trees will soon grow back, but those in Brazil probably will not. Data from the Brazilian Institute for Forestry Development indicate that in the 1987 burn season, more than 8 million hectares of Amazonia forest, an area the size of Indiana, were burned and similar amounts are reportedly being burned this year contributing millions of tons of carbon to the atmosphere. In contrast the forest fires in the western United States, about which we have heard so much, have burned an area one-tenth this size.

A.I.D. recognizes forest resources can only be sustained through improved management of existing forests, reforestation and afforestation. I was pleased to hear Dr. Brown's reference to the South Korean success, a program in which we have had involvement in prior decades. Today only a very small percentage of the world's tropical forests are being managed, however. The reasons are the lack of political commitment in the face of pressure to convert these lands to farmland and pasture, the misleading perception that economic returns from alternative land uses are higher, and limited experience in forest management. A.I.D. actively supports a number of programs to develop management strategies for natural forests and to change government policies which encourage slash and burn agriculture.

I would make one last point with regard to donor coordination in the energy and forestry areas. A.I.D. has embarked on a number of activities to encourage other bilateral agencies, as well as the multilateral development banks to support environmentally sound energy activities and to encourage new forestry activities. The United States cannot do this job by themselves.

For example, last June A.I.D. convened a meeting of environmental officers from the major bilateral assistance agencies at which we agreed to work together to develop environmental guidelines for our energy assistance activities. In October of this year, there will be an energy research donors meeting where A.I.D. will propose that a formal energy donors working group be established to assess ways of integrating environmental criteria into investment planning and policy development across the board in developing countries.

A.I.D. has also participated actively in the development of the global Tropical Forest Action Plan and is working with other donors and host country governments to assess forest resources and needed management activities in more than 60 countries.

Let me summarize briefly with four points.

First, A.I.D.-countries contribute only a small fraction at the present time of global carbon dioxide emissions from fossil fuels, and even with rapid economic growth, it will remain a small proportion of global emissions.

Second, promoting energy efficiency is an important component of our efforts in developing countries, but new energy sources will still be needed, both conventional as well as renewable.

Third, deforestation contributes to global climate change, and A.I.D. in conjunction with other donors in developing countries is supporting efforts to reduce current rates of deforestation and to promote new reforestation.

Fourth, the interactions between population growth and environmental management are complex, but rapid population growth clearly affects the environment adversely including global climate problems.

Thank you very much, Mr. Chairman, for your time.

[The prepared statement of Mr. Bissell follows:]

STATEMENT OF
RICHARD E. BISSELL
ASSISTANT ADMINISTRATOR
AGENCY FOR INTERNATIONAL DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
SEPTEMBER 20, 1988

Thank you, Mr. Chairman. I appreciate the opportunity to testify before this committee on the very important and complicated issue of global warming. We share your concern about global climate change and its effect on the prospects for sustainable, long term development in the third world. This past summer has been a constant reminder of the possibility of major changes in global climate patterns and has provided a sample of what the impact of such changes might be.

There is considerable debate about whether we have begun to experience the effects of global climate change or whether recent weather patterns are part of normal cyclical variations. I cannot answer that question. However, even if the heat and drought of this past summer are simply part of a normal climate cycle, this recent experience gives us some idea of the conditions that might exist in years to come if many of the current scientific predictions about long term global climate changes prove accurate. The effects of this summer's drought have clearly been serious, sharply reducing U.S. agricultural output and creating severe hardships for many farmers. Fortunately, the availability of stockpiled U.S. grain and federal drought relief have mitigated some of these problems.

The potential effects of global climate change---such as sea level rise, changes in weather and rainfall patterns and the distribution of forests and productive agricultural lands---are likely to have far more serious consequences for people living in the developing world than for us.

In Bangladesh, the severity of the monsoon floods has been increased by the growing destruction of the upland watersheds and higher than usual tides which appear to have slowed the rate at which the flood waters normally flow into the sea. Water now covers more than two thirds of the country, leaving approximately 30 million people homeless and this is just the beginning. Millions of tons of rice have been destroyed; roads, power and telephone systems have been severely disrupted. Food supplies which are never adequate are now almost non-existent and many health experts expect catastrophic health problems when the flood waters recede. Major outbreaks of cholera, respiratory disorders, dysentery and other intestinal diseases are feared.

The African drought of 1984-86, in combination with poor government policies, put more than 200 million people at risk. Hundreds of thousands died and the future of millions of children is bleak because of extreme malnutrition. The situation would have been even worse had it not been for the massive relief efforts of western governments and private voluntary organizations. U.S. citizens alone contributed an average of more than 60 pounds a person to the African relief effort.

High rates of population growth in developing countries, in some places between 3 and 4% per year, have overburdened traditional systems of agriculture, accelerating deforestation and desertification and have contributed to urban growth of a speed and magnitude not known in developed countries. These environmental effects and their impact on the people are starkly obvious in these poor countries, particularly when combined with conditions such as the drought in Africa or flooding in Bangladesh.

Developing countries which are already operating at the margin, with barely adequate food, health care, or shelter, are not likely to be able to make the adjustments necessary to cope with major changes in agricultural patterns, forest cover, water resources and quality of life. These countries simply do not have the financial, technical, or natural resources to absorb the effects of such changes.

analyses, however, consider only supply-side strategies for providing energy. The Bank has no requirements for the consideration of non-CO_2 demand reduction measures, such as efficiency or conservation improvements, as alternatives to proposed loans to support increased energy supplies. Indeed, only a minuscule portion of the World Bank's energy portfolio has ever been devoted to conservation, efficiency, and renewable energy sources. Even the structure of the World Bank's energy department guarantees that alternative energy investments receive short shrift. The only technical expertise on conservation and end-use efficiency at the Bank resides in an internal "consulting" group, which provides advice only upon request and does not have the power to propose alternatives to investments intended to increase energy generating capacity.

The effectiveness of the U.S. bilateral energy program -- both in terms of benefits to the public in the developing world and in reducing threats from the greenhouse effect -- will also be increased by a greater emphasis on least cost planning. This is particularly true for those countries which receive large infusions of capital in the form of Economic Support Funds (ESF) -- primarily Egypt and Pakistan. Through development assistance in other countries, A.I.D. is in a strong position to encourage conservation investments. The bilateral energy program in S. 2667 should direct the Agency to double its energy expenditures to not less than $120 million per year, with a strong emphasis on efficiency, conservation, and renewable energy sources.

Nuclear energy has been proposed in some quarters as the preferred solution to the problem of greenhouse warming. While atomic power is a CO_2-free technology, it has other serious risks that at present make it the least attractive alternative to fossil fuels. The current generation of nuclear reactors still entail the unacceptable danger of accidents. The problem of disposing of waste that will remain hazardously radioactive for many hundreds of thousands of years still has not been adequately solved. Nuclear energy carries the inherent danger of weapon proliferation. Atomic power suffers from a critical lack of public confidence. And nuclear energy, of all feasible alternatives to fossil fuel burning, is the most expensive. While the nuclear option may be worthy of consideration as part of public debate on ultimate solutions to the greenhouse problem, increased reliance on nuclear power at present would be premature.

This concludes my prepared testimony. I will be glad to answer any questions you may have.

Senator **Wirth**. Thank you very much, Dr. Wirth.

We have a vote going on, and I am going to have to go over and cast my vote, then come back. Let me make the following suggestion.

What I would like to do, if I might, Dr. Repetto, is to pursue a little bit with you how we go about strengthening the financial incentive package and the same sort of thing that Mr. Breck was talking about in this legislation. How do we set up a process to look at this and work on this?

Then I would like to pursue a little bit, Dr. Wirth, some of your comments and that of the other environmental organizations.

I would like to, if I might, Dr. Brown, talk a little bit about how we might go about packaging or figuring out more systematically what to do in a population area.

I am not sure—Dr. McNeal or Mr. Bissell, you all have been terrific in being up here and spending a good part of the morning with us. And if you all want to depart please do so. If you want to stay for the good of the cause, we would appreciate that too. But you all have been terrific.

Is that all right with you all? Why don't we break for about 10 minutes? I will go over and vote and come back and maybe we could just pick up on those areas and we might dispose of those pretty quickly.

What I am looking for is the ability, particularly in the population area and in the financial incentive area, to see what next steps ought we to be taking, what process ought we to be setting up during the remaining months of this year before we come back into the next session. Think about what kind of a group ought to be put together or what kind of legislative process or legislative language ought to be put together. Is that all right, Mr. Breck?

Mr. **Breck**. Right.

Senator **Wirth**. Thank you very much. I'll be right back.

[Recess]

Senator **Wirth**. I appreciate all of your patience. There is not much we can do about the timing of a vote.

Mr. Breck, let me pick up on your suggestions related to the financing mechanism. You pointed out the World Bank and IDA own $100 billion of the third world debt and that trading debt for conservation isn't a good idea because, as I have notes on what you said, it would cost the third world countries to manage what they might receive, and they don't have the funds to do that. And there really isn't any incentive because they are not going to pay back the debt for the most part anyway. Is that right?

Mr. **Breck**. Yes, that is especially true for a place like the sub-Sahara.

Senator **Wirth**. I understand.

We have to give perhaps incentives to our banks, enhanced incentives, perhaps being able to sell whatever tax credits they may have since they don't pay taxes.

Mr. **Breck**. Yes.

Senator **Wirth**. And direct funding to A.I.D. or some other agencies for help to third world countries to manage this debt.

Mr. **Breck**. Yes, cash.

Senator **Wirth**. Cash.

Let me, first of all, ask you. There is a lot of discussion about trading debt for rain forests. You hear that around a good deal, and I guess EDF and some other groups had started some of that. The first trade occurred someplace in Latin America.

Mr. BRECK. Costa Rica.

Senator WIRTH. In Costa Rica.

Mr. BRECK. There have been three trades that I know of: Bolivia, Costa Rica and Ecuador. Maybe there are some others that are taking place now.

Senator WIRTH. Let me ask you, first of all, a broader question. What are the differences between Uncle Sam coming in and trading debt for a rain forest or coming in and trading debt for locally owned banks, manufacturing companies, railroads, transportation systems, mining, natural resources?

Mr. BRECK. Well, Uncle Sam won't be able to own those things, the latter things in a foreign country. We are not going to end up owning—the United States Government is not going to own a mine in Chile. That isn't going to happen.

Senator WIRTH. Why not?

Mr. BRECK. I don't think the Chileans would accept that.

Senator WIRTH. I agree with you. Theoretically, what is the difference between the two? The point is isn't there potentially a danger of our saying we are going to go in and trade our debt for other resources, and you go in and then you start to trade your debt for other more economic resources, and you get right back into a cycle of economic imperialism from north of the border.

Mr. BRECK. You make a very good point.

Senator WIRTH. I don't know. I'm asking.

Mr. BRECK. People talk very casually about swapping debt for conservation, but to do it on the scale that is needed, we are talking about billions of dollars. There is a lot of acreage down there in Latin America. There is a lot of acreage in the Zaire rain forest. If you are going to preserve that, we are talking about a great deal of money. We are talking about billions of dollars. We are talking about an ongoing program over 50 years.

Now, I don't know how we are going to do that. That is very, very difficult, and it may require enforcement measures and political measures that we haven't even begun to think about yet. When you talk about making sure that a rain forest is preserved in areas where you have very little political control, badly organized governments, tribal problems—in a place like Costa Rica, you have 10 percent population growth because you have 3 percent natural population growth plus 7 percent refugees—how do you stop people from cutting down forests to find a few hectares to live on? Well, these are very, very difficult problems. And I think it is very hard to see how we are going to do that, but we have to do it.

Senator WIRTH. Dr. Repetto and I were talking yesterday about developing—looking at what we have in terms of legislative language in our financial institutions, what our relationships are from the Federal Government to our banks, to the World Bank, to the Latin America bank and so on, thinking that maybe what we ought to be doing is looking away from our jurisdiction here in this committee to overall our jurisdiction in the Congress over various financial institutions, and that we ought to see if we can come up with or start to explore legislative language focusing on our financial institutions related to the developing world.

Mr. **Breck**. You are absolutely right.

Senator **Wirth**. I am also on the Banking Committee, and it just seems to me that there is a great overlap between what everybody in the country is talking about and this enormous debt overlay. Isn't there an opportunity to put the two together in a creative fashion? I don't know, but you're the financial expert. Dr. Repetto is the rain forest economist, forest products economist. It seems to me we ought to be able to figure something out that is a little more creative than what we are doing now.

Mr. **Breck**. We probably should have Senator Bradley here because he has been the outstanding Senator on third world debt relief. He has been really very good.

You're right. We should be talking to the Treasury. We should be talking to the Comptroller of the Currency. It is a linked problem, and it is very hard to solve politically because the Treasury has its own agenda which is, of course, not to rock the banking system and yet, we are going to have to.

Senator **Wirth**. Dr. Repetto, what do we do as the next step? I agree with you we have to do it. It seems to me that there are some opportunities here that we ought to be exploring. I am not a financial expert. I am trying to figure out how do we get your great expertise, the two of you and others, together to come back to us and say, well, these are some ideas that you ought to explore. This is the sort of legislation you ought to be thinking about.

I am not asking you because I have any thoughts on this other than somehow there is an opportunity out there that we ought to be looking at. Bob?

Dr. **Repetto**. Senator, it seems to me that the nub of the various plans, Senator Bradley's and Mr. Robinson's of American Express, is really an exchange of paper; that is, that the commercial bank holders of third world debt get a more secure assets guaranteed backed by some international institution or a combination that is worth the same amount as the market discounted value of the third world debt. In other words, a lot of the third world debt is being sold at 10, 20, 30 cents on the dollar. Okay, well, they would get paper that is worth that market evaluation of what third world debt is worth, but it would be a secure asset, and that the issuer of that paper, whether it be a new institution or an existing institution, would assume the third world obligation, third world debt, issue debt relief and in exchange get policy commitments from third world governments as to how they are going to manage their economies to enable them to continue healthy growth and to service the remaining debt. That is the nub of these proposals with the different variants that are on the table.

Now, it seems to me that at that stage where there is an institution, be it the World Bank or some new offshoot, providing debt relief to the third world governments in exchange for policy commitments, there is an opportunity to make that linkage between rational energy policies, rational agricultural policies, rational population policies, rational forest policies, and so on that together make up a more sustainable development strategy that will enable these countries to go forward and not get into trouble again. And I think that is the critical point of intervention, Senator, where something can be accomplished.

It may not be primarily a commitment to set aside so many million acres in national parks, but rather to manage their entire economies, their entire rural sectors in a more sustainable way.

Senator WIRTH. Therefore?

Dr. REPETTO. Therefore, where the attention I think can be most usefully devoted is by trying to not create a whole new framework for rationalizing the third world debt situation, but to work with, say, Senator Bradley and other proponents of these plans to expand the framework of their plans, of their proposals, to include these considerations bearing on climate, forest, energy, et cetera that we think are important to sustainable development. That involves working with the World Bank, for example, the IMF.

Senator WIRTH. Mr. Breck, how would we go about doing it? Are there a number of people with the expertise that you have in New York in the financial markets who have thought about this?

Mr. BRECK. Yes, there certainly are, and they all disagree with one another about this.

Obviously, at NRDC we can put something together. We can come up with some sort of a plan.

But just for myself, can we just do one thing right? For example, could we get A.I.D. to put up a sizable amount of money to preserve a certain amount of rain forest somewhere? Indonesia. Could we get A.I.D. to set up a demonstration project in Indonesia, for the sake of argument, where we would commit the maintenance costs for some period of time on a very large hunk of real estate where we would pay the cost, where we would pay the fencing and we would pay the game warden, where we would, in effect, take the responsibility for it? I bet you we could split the cost with the Japanese and the Germans and some other people who have some money. I think that would be constructive. I would like to see something like that in the bill.

My experience with all of these things is you have to start with one real deal. You can't generalize.

Senator WIRTH. If Citibank, for example, owns a lot of debt, and they are going to write it off 70 cents on the dollar—let's assume.

Mr. BRECK. Well, they won't accept that, but——

Senator WIRTH. You and I know that that is going to happen at some point.

Mr. BRECK. One day.

Senator WIRTH. Or it seems to me that it is pretty clear that that is going to happen.

Is there any way in which that 70 cents—let's use the hypothetical 70 cents that gets written off by X bank—let's not use Citibank, any bank. Is there any way in which there is value in that 70 cents that can somehow be sold, securitized? Is there something you can do with that 70 cents that gets written off that would have some kind of value or could be written off and used in some way?

Mr. BRECK. I don't think so. I think this has been one of the myths of the debt problem, that somehow this discount can be recaptured for the benefit of the countries themselves. This just isn't true. If you loaned me $100 and I say, well, you know, I'm not going to pay you back, well, then automatically the loan is worth a great deal less. And that is what the countries have done. By their refusal to pay on time, they have lessened the value of the loan.

Senator **Wirth**. But it is worth something to X bank to be able to write that off from a dollar to 30 cents. Right?

Mr. **Breck**. Well, yes. The 70 cents is fine at current tax rates. That at 34 percent. That is worth about—it is 24 cents on the dollar alone. The only thing it is worth to them if they write it off is a tax deduction. So far they haven't written those loans off for tax deductions. They have taken reserves, but they haven't actually taken the full loss. They have taken minor losses compared with the full amount of it.

The commercial banks are going to be very difficult to deal with.

Senator **Wirth**. What kind of incentives can we give to them where—it just strikes me we are dealing with the potential of something. I don't see what it is, but somehow I have the feeling that when we are looking at all of this writeoff and all of this debt that exists and problems that exist there, that we ought to be able to figure out how we might use that.

Mr. Bissell?

Mr. **Bissell**. Could I clarify something please, Mr. Chairman, because I am also chairman of the interagency task force working on the debt-for-development and debt-for-conservation swaps. Last fall Treasury asked A.I.D. to pick up this particular effort with regard to developing countries.

There are two issues here that we are dealing with which is why I would have a certain reservation about moving too rapidly on new incentives for the banks. One is that banks keep two sets of books for all intents and purposes, all that we know of. They keep a set of tax books which last fall Treasury or the IRS in ruling 87-124 clarified that they would achieve the same benefits by donating their LDC debt to, say, conservation organizations as they would be selling it in the secondary market. This is a very important step in terms of making it possible, creating a level playing field, for banks on their tax accounting to, in fact, come up with a reason to, given all other things, go ahead and donate it to a conservation organization.

On the accounting side—that is, the profit-loss, their set of books with which they account to their shareholders—the question is still open, which I think is really being referred to here, where we expect to have some answers within the next few months. That is, the SEC has been unable to move in terms of—the Comptroller of the Currency has been unable to move in terms of an actual ruling with regard to the effect on their profit loss statements in the absence of any actual deals, swap deals, being put to them for a ruling.

Because we are now in the process, I think of seeing some being completed in several countries in Latin America and Africa, we should see before the fall is out those issues which may include augmentation of assets because if they have debt that is on their books at 7 cents on the dollar and it's actually swapped to be worth, say, 85 cents on the dollar, those rulings may determine that, in fact, there is enough benefit for the banks that we may have to give them no further incentive. But we won't know that until we have an actual ruling which can only be triggered by one of these deals in Costa Rica or Madagascar or Peru or someplace else actually coming to them for a ruling.

And so, we are working with the banks and with the conservation organizations, particularly through the newly formed Debt-for-Development Coalition here in Washington, to try to bring one as soon as possible to that agency to have a ruling. And then I think we will know exactly what kind of incentives we need or don't need.

Senator WIRTH. Les?

Dr. BROWN. I wanted to make a general point on the broader set of issues in terms of debt and sustainable development. The debt problem is a serious one. The banks would like to get rid of them. I'm sure Citibank would like to get rid of this whole mess in some way that would be suitable.

Developing countries are going nowhere. We are seeing rapid population growth. In effect, we have taken away the social forces that reduce population growth in Latin America. They are simply not operating now. The improvements that normally would lead to smaller families are not working. So, we have continuing rapid population growth, continuing rapid environmental degradation on the scale that is going to affect economic trends and is already affecting in some countries.

Now, it seems to me that—in fact, we proposed this in State of the World last year in the last chapter in a general sense—that if we could set up some sort of new institution—and I am not keen on new institutions usually, but one that would be represented in its governance by the bank and the fund, and which would be funded partly perhaps by the Japanese and the way that we funded the Marshall Plan and then its job would be to buy up the discounted debt for a country that would come up with a sustainable development strategy.

I don't think setting aside reserves is going to work. I have seen too many because where with population pressures, the demand for firewood just goes right over those boundaries. There is no way you can protect them not even the governments in question, much less us from here.

What I think would be an important advance in sustainable development would be to get countries to come forth with their sustainable development strategies which, as Bob indicates, would be an energy and agriculture and population biodiversity, et cetera, forestry. If Peru comes up with a policy that really is recognizable as a sustainable development strategy, then this new entity would begin to work to purchase the discounted debt and to arrange to get Peru back on a path where it could begin to develop in a sustained way and where the debt burden, which is now actively interfering with that, would be removed.

But I think it is going to take some sort of a new initiative. The existing approaches and the efforts by the bank, the Fund or anyone else simply are not working. Everyone realizes that now. I think a major new initiative is needed. I think the idea of trying to set aside nature reserves is over the long term, without dealing with basic things like incomes policy and population growth and so forth, is like trying to pour water uphill.

Senator WIRTH. Do you have any reaction to that, Mr. Breck?

Mr. **Breck**. Yes. I think the moment is coming, and I think it is maybe the heat of last summer which is actually going to be the catalyst for this.

I used to think that it wouldn't happen until the debtor countries themselves were driven so hard to the wall that they actually said we can't pay any more and, in effect, defaulted. I thought only that would provoke the sort of international conference I think we are going to need on that. But maybe the ecological problems we are now encountering will be the catalyst and we will be able to get together to settle this problem.

Yes, I agree. I think we have to settle this problem. We can't go on for 20 years with the development of these countries held up by this massive debt. The very fact that we are now willing to grant the principal in the sub-Sahara—and I think that is what is going to happen in Berlin—indicates that the principal would also hold true for Latin America as well. That is where—at least in Brazil and Colombia and Peru—we really have to worry. Not only do those countries have a lot of rain forests, but they are right next to us in terms of their location.

Senator **Wirth**. What is the sub-Saharan initiative in Berlin?

Mr. **Breck**. Secretary Baker indicated in Toronto that we might consider debt forgiveness in certain special cases, namely, the 22 countries of the sub-Sahara where you have marginal GNP.

Senator **Wirth**. Oh, I see.

Mr. **Breck**. This argument has been going on for some time. I did work for the State Department going back three years, and I went and talked to Deputy Secretary Whitehead about it. And the idea of debt forgiveness in the sub-Sahara—he just laughed. He said you want me to go to the World Bank and tell the World Bank to forgive debt? He said I think that is a terrible idea.

Well, it was a good idea. I think we are now going to do it, and that is a good step forward. But we are also going to have to do it in Latin America, and it is going to be very painful and very expensive.

Senator **Wirth**. I am not sure how much more we can do here at this point, but I would just invite from you or, Dr. Repetto, from you or from A.I.D. or, Les Brown, any ideas that you might have that you think we ought to be pursuing either here or on the Banking Committee which has a set of jurisdictions with our international financial institutions and our national ones which, of course, spill over on the tax side which is Bill Bradley's concern.

As you know, we are somewhat compartmentalized, not a great deal, but somewhat compartmentalized. But if you take this committee, the Banking Committee and the Finance Committee, then we pretty much have a jurisdictional handle there, and I think we might be able to do some interesting things or at least start some processes of thinking of maybe some legislative ideas.

So, I would certainly welcome anything that any of you might want to contribute to that discussion. If you could get that to us, we are going to begin to think about how we set up for next winter and where we go from here with this, and we would appreciate any thoughts you might have.

Dr. Repetto?

Dr. Repetto. World Resources Institute was asked by UNDP and Canadian Aid and USAID to undertake a feasibility study of innovative conservation financing mechanisms. We have been underway in that study for a couple of months now. We are starting to produce some initial papers which are very much in this direction. We would be very happy to share them with you.

Senator Wirth. What we ought to do is think of putting together some kind of a working group of various—maybe that already exists, does it? We are represented here by people who have had a lot of experience. We don't want to end up with people all disagreeing with each other. You know, we're agreeing on 60 percent of these items and the other 40 percent we have to work our way through. You know how that gets done.

Dr. Repetto. That is exactly what we are trying to do. We have tried to bring in to our advisory panel a lot of the people from both the official and the NGO and the financial and conservation groups.

Senator Wirth. Dr. Brown, let me jump to the population item, and then we are going to close here pretty rapidly, if we might.

I had suggested earlier it seems to me that we ought to have a more systematic understanding on the committee of the steps in the area of population that we ought to be pursuing. One, we talked about funding a little bit in my earlier discussion with Mr. Bissell. Second, we talked about providing other kinds of technical help which you had suggested to other nations around the world. Third, international cooperative ventures. The Soviets have now become involved, as I understand it, with the U.N. population efforts as we were pulling out. There must be a variety of steps that ought to be taken.

As I have been involved in this issue for many, many, years, but it has really peaked over the last nine months, I am struck by the fact that the population issue receives remarkably little attention either because people haven't made the connection, they are politically afraid of it, or have a predilection that we shouldn't take it on or whatever it may be, and that we have an obligation to try to get it back up a little higher on the agenda.

What I am looking for is a group that is systematically looking at the population issue. Should we be pressing that and encouraging that? Should we be writing letters to people asking them to get together? I am not quite sure. Or maybe plenty is being done now and we have a lot of knowledge and expertise. I don't know. I'm asking you. If you were sitting where I am on the population issue, what would you do next? Or are we doing enough?

Dr. Brown. I don't think plenty is being done now. It is an issue that has—I suppose there are two things. At the official level, it has sort of fallen into disfavor.

Senator Wirth. I've noticed.

Dr. Brown. That affects the way—I mean, I think there is a public feeling if the administration won't do anything about this or won't provide leadership of the sort that the United States has provided for a couple of decades, then it is kind of frustrating and people find it difficult to figure out what to do. That is sort of one thing.

The other thing is that the linkages between population growth and many of the problems that we are dealing with, whether it be climate change or third world debt, are not all that clear in the minds of most people. People do link population growth and food, and when there is famine in Africa, they respond to that. So, I think partly the perceived link in the public mind between the sort of population growth we are experiencing in the world and many of the problems we are facing is not a well developed one. So, I think anything that can help out there would be good.

But if you think it is not well developed here, then you ought to be in some third world countries.

You asked earlier about the resources that could be used in this field. One of the things we have seen in recent years is a number of countries in Africa come forth, countries that had no family planning or population policies at all come forth and say that they are beginning to recognize that they have to get the brakes on population growth for economic and environmental reasons and asking for help.

Unfortunately, oftentimes the help has not been there. We used to worry about how to convince African leaders to do something. That is not so much the problem right now. It is how to respond to their requests for assistance.

Senator WIRTH. So, what do we do next? What is the therefore? What do we do? Where do we go from here?

Dr. BROWN. One of the most useful public education devices I think is available is at two levels: looking ahead to see where things go and asking ourselves what if we continue on this population trend. What does it mean for the world? What does it mean for individual countries?

As I am sure you remember, we had in 1980 the Global 2000 study which was an initial, sort of quick effort at trying to do that. What I think we should be doing is maintaining that study and updating it every 3 or 4 or 5 years taking into account new information, new understanding of processes, new technologies, whatever and to use a document of that sort as kind of a touchstone for international discussion of this complex of issues that we have been talking about this morning that are involved in this bill. And it may well be that, although a few years ago the interest was not there, as Mr. Breck was indicating, this past summer has convinced a lot of people that we do need to be paying attention to some of these issues on the scale that we have not been doing.

The thing that I think would be most useful that we can help do is help individual third world countries do these longer term kinds of things and not just on the computer program, which I think is a very useful device that Mr. Bissell was describing, but actually do some studies and get them out where people can chew on them and begin to understand them.

Senator WIRTH. Let me ask you this, Dr. Brown. You might just think about this, and again we would be happy to hear from you on this. If you were sitting where I am, where we are, and looking at this piece of legislation and what ought to be added, what steps ought to be taken within this bill and in turn stimulate other debate, what would they be? I would really like to hear from you on that. You know a lot about this area and you have a lot of people.

Should we be gathering a group together like we were talking about in the financial area and in the debt area? Should we in the population area be reaching out to a variety of other resources that are out there, people who have thought about this and maybe the time has come—I think it has—to see if we can get the attention back on population issues? People have kind of ducked it and avoided it and so on. Maybe we ought to be pulling together a group to be working on this. I don't know, but you know about this. You know this area a lot better than probably anybody in the room, and we would like to hear from you. Would you do that?

Dr. BROWN. Let me see if we can get something together for you.

Senator WIRTH. That would be great.

The final item I wanted to talk about, if I might, was to go back to your testimony, Dr. Wirth. In your testimony on page, let me just quote from you because I want to ask you about this. In the second paragraph you say: "We understand"—"we," as I understand, being the Sierra Club and EDF and NRDC—"that the purpose of S. 2667 was to stimulate debate on this important issue and to lay the foundation for a further legislative initiative in the next session of Congress. However, the organizations I represent today have serious reservations about the authorization for the nuclear demonstration project currently contained in Title VII of the bill. For this reason, as discussed below, we would find it impossible to support a bill such as S. 2667 introduced in the next session so long as it continues to include this provision."

I just wanted to ask you about that. We hadn't asked NRDC or EDF or the Sierra Club to comment on this particular provision, and this was in here, and I figured that you all had decided to put that in here for a very specific reason. So, I really wanted to ask you about it, if that's all right.

Dr. WIRTH. Certainly.

Senator WIRTH. One, can you tell us what is in the provision in S. 2667, what are the specifics of title VII? What does that say?

Dr. WIRTH. Mr. Chairman, as I understand title VII, it would authorize the construction of a nuclear demonstration project with several criteria and with a deadline that the project be on line and connected to a utility grid by the year 2000.

Senator WIRTH. And what are the criteria in that?

Dr. WIRTH. Mr. Chairman, I have that section right in front of me. The criteria are: number one, that the project would permit modular design; second, that it exhibit passive safety; third, that it is adaptable to standardized construction and licensing; fourth that it's cost effective; fifth, minimize the volume of nuclear waste and sixth, prevent diversions of radioactive material for use in nuclear weapons.

Senator WIRTH. Let me ask you another question. How much funding is authorized in this legislation compared to what we are currently spending on nuclear R&D?

Dr. WIRTH. Mr. Chairman, as I understand it, there is a total of $500 million in this legislation authorized for this demonstration project. I'm sorry, but I am not familiar with the total amount that is generally available for nuclear R&D.

Senator **Wirth**. Is it the case that what is in here replaces what is currently in the Department of Energy's nuclear budget?

Dr. **Wirth**. That is what I understand to be the intent of the provision, yes.

Senator **Wirth**. That is what this does, isn't that right—not the intent, but that is what this does, isn't that right? And, what we are really spending in here is half of what DOE is currently spending on nuclear.

Dr. **Wirth**. I'll take your word for that, Mr. Chairman.

Senator **Wirth**. That is the case. So, effectively what you all are doing is saying, among other things, that you oppose a 50 percent decrease in the R&D funding going for nuclear.

Dr. **Wirth**. Mr. Chairman, let me describe generally what our concerns are about this provision.

Senator **Wirth**. No. I just want to know if that is the case. You do realize that that is what is in here.

Dr. **Wirth**. We are particularly concerned——

Senator **Wirth**. I just want to know if you understand what the specifics of this are.

Dr. **Wirth**. Mr. Chairman, let me just say, first of——

Senator **Wirth**. If the answer is no, then go ahead.

Dr. **Wirth**. We are very appreciative of this legislation, generally. We are very supportive of the initiative that the committee has taken, as I think my written testimony and my oral testimony—I think both of those pieces were quite clear on this point.

We are quite concerned about the nuclear option that has been proposed as at least a partial solution to the global warming problem because of well-known problems with this technology, including the risk of accidents, waste disposal, weapon proliferation, and lack of public confidence in this technology.

Most of all we are concerned that—not most of all, but we are also quite concerned that among the options that are set out that are available to deal with the global warming problem, the nuclear option is among the most expensive, if not the most expensive.

I would note that the first part of your bill sets out a very clear regimen for deciding where money should be allocated among different energy technologies. We are concerned that the demonstration project that is singled out in this bill would disrupt that process and would prematurely put money into a demonstration project that may not be necessary.

Senator **Wirth**. Let me ask you some other questions. What percentage of the overall R&D in the bill goes to nuclear?

Dr. **Wirth**. I'm sorry, Mr. Chairman. I haven't figured it out.

Senator **Wirth**. It's a little less than 10 percent. I think the record would show that this is the case. And you are quite right in citing all the well-known problems of nuclear, but if there are a whole series of well-known problems on nuclear, isn't that a good reason for starting all over again? To say this hasn't worked, it seems to me that you have all these problems and we ought to try to figure out how to start all over again.

Let me ask you also. Have you all examined this and decided that it is not possible—you are sure that it is not possible—to develop a safe and cost effective nuclear program? You have decided that is the case. Is that right?

Dr. WIRTH. Mr. Chairman, we are not categorically opposed to nuclear——

Senator WIRTH. Wait a minute. Wait a minute. You have said in this statement that you are not going to support any bill that has any legislation related to nuclear in it. Your three organizations have decided that it is not possible to develop a safe and cost effective nuclear program.

Dr. WIRTH. I'm sorry, Mr. Chairman, but I'm afraid that you have misstated my——

Senator WIRTH. I am just reading from your testimony, Dr. Wirth. "We would find it impossible to support a bill introduced in the next session so long as it continues to include this provision." That says to me that you have decided that it is not possible to develop what we set out in the criteria a safe and cost effective nuclear program, and that it would be—and you have also decided that it would be unwise public policy for us to see if we can develop a modular program, one that also addresses the issues of nuclear waste and proliferation. You have decided that that is something that we in good conscience should not do. Is that right?

Dr. WIRTH. Let me make two points.

Senator WIRTH. Let me just ask you yes or no. You have decided that it is not possible to do that and that we should not conduct any research to see if that is possible. That is correct, is it not?

Dr. WIRTH. No, neither of those points is correct.

Senator WIRTH. Well, then why do you say in your testimony "we would find it impossible to support a bill introduced in the next session so long as it continues to include this provision"?

Dr. WIRTH. Mr. Chairman, let me make two points about title VII of the bill. First of all, as we understand it, it establishes a deadline for this demonstration project to get on line by the year 2000. As I understand the purpose of title VII, it is to encourage the development of new technologies that have all of the items that have been listed that I read off before. But we know of no technology that is available now that could be on line by the year 2000.

Senator WIRTH. Neither do we. That is why we are undertaking the research.

Let me ask you a couple of other questions about this. You are representing on this NRDC and the Sierra Club and EDF as organizations. Is it my understanding that in making this kind of a categorical statement about not supporting this legislation, that that is a position that has been taken by the boards of the Sierra Club, EDF and NRDC?

Dr. WIRTH. Mr. Chairman——

Senator WIRTH. Is there an answer to that? Yes or no.

Dr. WIRTH. It is a position that has been taken by the staff of those organizations.

Senator WIRTH. Let me tell you why this is significant.

NRDC and EDF and the Sierra Club have gone around systematically to Members of the United States Senate whom I have been asking to cosponsor the bill. There were, I can assure you, Dr. Wirth, probably a score or more who wanted to go on the legislation. But the three environmental groups and others, to whom I refer, have gone around and systematically pushed them off the legislation saying that they were going to raise all kinds of political problems for them in their own backyards for doing so.

Now, if you are going to do that sort of thing, it seems to me that that is a very important public policy decision to have made, that you have decided that there is no way that we ought to, looking at the global warming issue, in good conscience—that there is no way that we should be exploring any future for nuclear energy, looking for a safe and cost effective nuclear program, that you will not support this bill and, in fact, will actively work, as has been done, to keep people off this bill, and will clearly by implication in here do so in the future.

Now, this is probably the most far-reaching piece of environmental legislation that we have seen in the United States Senate that I know about, reaching a whole variety of issues. I am bluntly surprised that this kind of action has been taken by those three organizations. I know a lot of people in those three organizations who bluntly don't agree with that.

I raised those points today because you all raised them. I didn't come just prepared to discuss this particular issue, but you all thought it was important representing these three organizations to put that statement in the testimony. I would ask you, as I have asked Mr. Breck for ideas, to come back to us and asked Dr. Brown to get back to us with ideas—I would like to hear from these three organizations what process has been gone through and how you have reached these decisions apparently without much knowledge of the specifics that are in here long term about this.

I appreciate all your work on the other parts of this legislation, but you all raised the issue today, and I just thought it would be appropriate for the record to reflect a response to that. From the perspective of somebody who has worked pretty hard on this sort of thing, I find it very hard to understand.

Dr. WIRTH. Well, thank you, Mr. Chairman. I can assure you that we will take the invitation to discuss this further with yourself and your staff.

Senator WIRTH. You might want to discuss it with your various boards and see if all of them agree with that categorical position as well. I think that would be important to do.

Dr. WIRTH. Mr. Chairman, let me make quite clear that NRDC and to my knowledge, the Sierra Club and EDF have never been categorically opposed to nuclear power. We are concerned about the——

Senator WIRTH. "For this reason, as discussed below, we"—being EDF, NRDC and the Sierra Club—"would find it impossible to support a bill such as S. 2667."

Dr. WIRTH. Mr. Chairman, with all respect, that refers to the provision in the bill and not our general feeling about—not our general approach to nuclear power. We are concerned about, as I said, the risk of accidents, the problems with waste disposal and the problems of weapon proliferation.

We are quite concerned about a demonstration project that will actually be built on the ground, in other words, a nuclear reactor that will actually exist, and not only that, but a nuclear reactor that will exist and where there is a deadline that it is established by the year 2000 when the current generation of nuclear reactors continue to have many of these major problems.

I would suggest, Mr. Chairman, that——

Senator WIRTH. Well, if that is the case, Dr. Wirth, like on anything else, people come in and say, well, maybe that is an unrealistic deadline, or maybe that is an approach, that everybody does on a steady basis. You heard Senator Murkowski up talking about the Tongass provision he doesn't like. Phyllis Shafley doesn't like the population provisions of the bill. There are a lot of people who have various problems with it, but they don't come in and say that the whole bill ought to go down the chute and we are going to oppose it until you take that ball out of there. In other words, we are going to take our ball and go home if you don't like this whole operation. It doesn't seem to me that that is a very—I would use the word advisedly—mature approach to something of such size as this.

I think it is time that we all get this out on the table right now, get it out early on. I am glad that you all raised it and give us an opportunity to do so because certainly a lot of the atmosphere related to this legislation and our efforts on that have been significantly poisoned by this kind of broad categorization of the whole legislation which I think has been unfortunate.

I would remind you that only last week on the front page of the Wall Street Journal, the only reference in discussion of this issue was me and the legislation getting hammered by one of these groups because of a nuclear provision, and no reference to all the other items that is in here. Now, that doesn't seem to be very much within the process. It makes it very difficult for us to do our job. I think that you all ought to look very carefully at the process.

Do you have anything else you want to add? We will look forward to hearing from you.

Dr. WIRTH. Mr. Chairman, why don't we leave it that we will take you up on your offer to discuss this with yourself and your staff?

Senator WIRTH. We have discussed it with them. It is not myself and my staff that I am concerned about. It's wondering what your organizations are doing.

Any other comments and thoughts?

[No response.]

Senator WIRTH. We thank you all very much for being here. It has been a long morning, but I really appreciate your time and attention. Thank you very much.

[Whereupon, at 12:09 p.m., the committee was adjourned.]

APPENDIXES

APPENDIX I

Responses to Additional Questions

Department of Energy
Washington, DC 20585

October 7, 1988

Honorable J. Bennett Johnston
Chairman
Committee on Energy and Natural
Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

On August 11, 1988 Undersecretary Donna R. Fitzpatrick appeared before your committee to discuss global climate change. Following that hearing, you submitted written questions for our response to supplement the record. Enclosed are the answers to those questions.

If you have any questions, please have your staff call Rebecca Thompson on 586-4277. She will be happy to assist.

Sincerely,

Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc:
Honorable James A. McClure
Ranking Minority Member

QUESTIONS AND ANSWERS

FOLLOWING THE

AUGUST 11, 1988, HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES

UNITED STATES SENATE

WITNESS: DONNA R. FITZPATRICK
UNDER SECRETARY

Question 1: You state in your testimony that the Greenhouse Effect has been the subject of research efforts at the Department for the past ten years. Could you describe what progress DOE has made in this decade of research in designing policy approaches to address the global warming problem?

Answer: The Department's Carbon Dioxide Research Program has been conducted for ten years. The goal is to provide adequate scientific knowledge to government and others for identifying and selecting responses to the greenhouse effect (i.e., climate change and carbon dioxide [CO2] fertilization, and their influences on natural and human resources).

To achieve this goal, the considerable uncertainties involved with the CO2 issue must be reduced. While there has been considerable progress, well documented in scientific literature, in reducing these uncertainties, DOE does not believe existing knowledge and understanding of the effect of increasing CO2 on complex interactive climate processes supports policy actions to drastically reduce emissions of greenhouse gases. The first step is to reduce uncertainties through increased understanding of the climate change mechanisms -- a study of global proportions.

To that end, the U.S. Government was instrumental in establishing the Intergovernmental Panel on Climate Change which I described in my testimony and we support the development of a complete scientific assessment and identification of needed future research.

Examples of research findings from the Carbon Dioxide Research Program include:

o An extensive intercomparison of four general circulation models concluded that although model simulations of the present climate often agree well with observations and with each other when comparing seasonal or annual averages globally, significant disagreements become apparent as the spatial extent is reduced, particularly when detailed, regional distributions are examined.

- A comprehensive estimate of the trend in global mean surface temperature over the last 130 years was developed.

- The data base for the Northern Hemisphere temperature-time series has been extended back to 1851.

- An automated global set of paleoclimatic data for 6000 yr B.P. is now available for testing the paleoclimatic simulations by general circulation models.

- Ocean CO2 measurements indicate high latitude oceans are strongest CO2 sinks accounting for 50 percent of anthropogenic CO2 emissions.

- Measurements of CO2 in the surface water of the Western Equatorial Pacific Ocean provides significant new information about the variability of a weak CO2 source in an area of the ocean that has not been extensively sampled before.

- The southern oscillation was simulated in a global climate model.

- The North Pacific Ocean was found to be a CO2 source in winter.

- a 200-year atmospheric record was prepared from measurements of CO2 in ice which made it possible to trace the development of the atmospheric CO2 increase up to the Mauna Loa record.

- The first climate model comparison and improvement strategy was agreed upon by the modeling community.

- A simple model has been developed to predict responses by plants, crops and the global biosphere to changes in atmospheric CO2.

- Increased atmospheric CO2 causes salt marsh ecosystems to increase biomass, improve water use and delay senescence.

- Field data from outdoor experiments involving food, forage and fiber crops provide convincing evidence that CO2 enrichment causes greater growth and productivity.

- Improved water-use efficiency of plants because of elevated levels of CO2 will measurably increase growth and dry weight gain of plants.

- In 1985, the Department of Energy issued four state-of-the-art reports concerning CO2 research.

Question 2: Your testimony also states that the Department's assessment has helped DOE to "identify future research areas to formulate effective policies". Ten years seems like a long time in which to identify future research areas. Could you describe these "areas" in which the Department has formulated policies?

Answer: There are two distinct policy considerations: those directed at slowing the rate of CO2 (and other radiative active gas) emissions, and those policy considerations dealing with potential adverse regional impacts created by different climatic conditions. While these different problems require different information for solutions, each also requires fundamental knowledge regarding CO2 emissions and the global carbon system, the climate's response to atmospheric CO2 change, and the consequent effects on the Earth's ecosystems. This research addresses questions of "why is a change taking place?"; and "what differences does it make?". Scientific inquiry must address these types of questions to avoid premature or, ill-advised action and to focus policies on the Nation's long-term welfare.

To address such policy considerations, the research goal is, and has been, to develop the scientific knowledge base for policy formation and governmental action in response to changes of atmospheric CO2 and its primary effects on the Earth's climate and biological systems. Achievement of this goal requires increased understanding of CO2 interactions involving the global atmosphere, biosphere, oceans, and cryosphere.

The results of this research have been documented in the Department's technical reports and scientific literature. They identify the following areas in which future research is required before effective policies can be formulated:

There is a need to improve understanding of the global carbon system:

- The sensitivity of the global carbon system, and hence the sensitivity of atmospheric CO2 retention, to perturbations of such magnitude is not now known.

- Gradual warming of the global climate on the order of several degrees centigrade may affect the ability of oceans and the terrestrial biosphere to retain CO2, thus casting some doubt on the theory that the present 50-60 percent range for atmospheric CO2 retention will apply over the foreseeable future. Feedback relationships of the global carbon system must be further elucidated as models do not systematically treat such interactions.

There is a need to improve knowledge of the global climate system:

- The causes of the differences among the models and between the data and the models need to be understood. This is essential to improve models for regional applications.

- Ocean heat storage capacity may be delaying the observation of greenhouse-induced climate change. Current ocean models are not adequate to estimate this delay. Therefore, continued ocean measurements and ocean model development are required.

- Clouds can counteract or enhance the greenhouse effect, but are included in the climate models only in a rudimentary manner. Improved cloud data and improved cloud modeling capabilities are, accordingly, required.

Research needed to understand greenhouse effects on vegetation includes:

- Experiments to evaluate interactions of CO2 and climate variables on vegetation. Multiple influences may enhance or slow plant growth and neither the direction nor the magnitude of combined effects is known.

- Biophysical system models of representative vegetation need to be developed and tested.

- **New field experimental data for confirming laboratory results and for validating model simulations are needed.**

The ultimate goal of the Carbon Dioxide Research Program is to provide adequate scientific knowledge to government and others for identifying and evaluating potential responses to the greenhouse effect (i.e., climate change and CO2 fertilization of vegetation, and their simultaneously induced influences on natural and human resources).

International action will be required if emission trends of CO2 and other gases are to be effectively slowed or reversed. Such international cooperation cannot be sustained by many governments over several decades without a credible and widely accepted scientific assessment addressing the issues just described. Developing a successful response to the greenhouse effect inescapably requires that we account for regional differences in climate, the associated resources and their use, and most importantly, the differential influences of the greenhouse effect on climate and resources at regional scales. This is the thrust of DOE's scientific research.

DOE programs include the development of new technologies which will meet our energy security and environmental needs. This new generation of supply and end-use technologies can contribute in a significant way to any international action to address global warming when science sufficiently reduces the uncertainties and an international consensus exists.

In addition to technology development, DOE is beginning four Congressionally-mandated studies which include analysis of policy options. The policy analysis, technology development, and scientific research activities are a vigorous response to the potential for climate change and will contribute to the formation of an international consensus. Such a consensus cannot form until science and policy analysis have advanced, and until the world community has the tools to effectively respond (the new technologies).

Question 3: You use the term "scientifically supportable" in your testimony. Do you believe current predictions and data regarding global warming and climate change can be scientifically supported?

Answer: Yes, for some of the global statistics. The greenhouse theory is that trace gases, including carbon dioxide, and water vapor, warm the Earth's climate. Indeed the Earth is some 30 degrees Celsius warmer than it would be without such gases. This is one reason the Earth's climate is different from the climates of Venus and Mars. So the greenhouse theory, simply stated is sound. Generally, what requires added "scientifically supportable" results is the human contribution to increased warming. Areas presently needing added "scientifically supportable" results include the rate of greenhouse gas-induced climate change, the magnitude of such change, the regional patterns of the climate change, and the effects or various interactions of clouds, temperature changes, ocean currents, and other variables.

Question 3b: What degree of certainty would the Department give to current predictions regarding the inevitability of a global warming?

Answer: DOE cannot provide a degree of certainty to current predictions regarding the inevitability of average global warming based on the current climate models. The climate models are not sufficient to provide the rate of greenhouse gas-induced climate change, the magnitude of such change, or the regional patterns of the change.

Question 4: Your testimony states that at present emission growth rates we will see a significant global mean temperature increase by the middle of the next century, yet the Department has repeatedly advocated waiting for further data to be collected before launching major policy initiatives. Are you concerned that mitigation and efforts to reduce CO2 and trace gases will be too late if we wait four or five more years to implement them?

Answer: No. The trends that are seen are not rapid changes. Therefore, it is probable that future scientific understanding and data will provide a better understood set of policy responses than choices that might be proposed at this time.

The Department's position is that we need to conduct research over the next five to ten years to develop the scientific knowledge base needed for long-term policy formulation and sustained governmental action. As I stated in my testimony, effective action must be based on international consensus and coordinated actions; such a consensus will demand both strong scientific understanding and time. Thus all these activities should be pursued now.

Our research to date has identified key uncertainties in the carbon cycle which will determine the amount and growth of the atmospheric concentration of CO2. It is also clear that we are unable to identify the regional effects based on the predictions of climate models. Further, the relationship between (1) the direct effects of increased CO2 on plants, (2) and possible climate change is not well understood. It would be premature to initiate policy actions without additional scientific data to substantiate them.

Question 5a: Why does the inability of models to agree exactly on regional climate implications forestall the development of mitigative strategies as discussed on page 2 of your testimony?

Answer: The models not only lack agreement in the magnitude of change, but also in the direction of change. The differences between the climate models and the observed temperature data for the midwest U.S. for example, range from one model resulting in a climate 4.8°C colder than the regional average to another model showing a climate 6.8°C warmer than the regional average. Even though all the models predict an average global warming for increased atmospheric greenhouse gases, such large differences in predicted regional temperatures, compared with the actual observations, may well indicate that there are basic deficiencies in the global climate models. Further research is required to determine the reasons for such differences in present models. Then, predictions of climate change can be improved, the degree of confidence in the predictions quantified, and mitigative strategies can be developed to address the needs of various regions and resources.

Question 5b: Would not any change in weather patterns, increases *or* decreases in rainfall, etc. be worth planning to avoid?

Answer: Changes in weather patterns and in climate patterns can be expected, even if there were no man-related causes. Thus, such variations are to be anticipated, but cannot be avoided. Some level of change in local climate is expected and accepted by the population -- an example is the change imposed by urbanization. Thus, the aphorism that "any changes in weather [or climate] patterns ... are worth planning to avoid" does not have universal value. The need for avoidance planning is a function of the direction, magnitude and rate of change, and, in making such a judgement, the interrelationships of natural change, range of annual variability, and the man-induced effects need to be understood. Hence, it is important that any estimates of change and plans to moderate or to avoid change be based on a more complete scientific understanding and prediction capability than we have available now.

Question 6: It was reported (*Energy Daily*, August 2, 1988) that Assistant Secretary Baynard expressed skepticism and even questioned the existence of the Greenhouse Effect. He stated that he "thinks it's folly to try to come up with a solution to the problem before we know what the problem is". Yet your testimony calls Clean Coal technology the answer to the Greenhouse Effect. Does Mr. Baynard represent the Department's views on this issue, or do his statements reflect his own personal views?

Answer: As I indicated in my testimony, DOE believes that the potential for global climate change is an important concern of the Department and it has been so for a number of years.

However, as I also indicated in my testimony, there is considerable uncertainty surrounding the climatic implications of increasing greenhouse gas emissions. In Mr. Baynard's speech to the National Coal Association, he was elaborating on those uncertainties and their implication for policy formation. Therefore, Assistant Secretary Baynard's comments were reported out of context.

There are, in fact, virtually no completed analyses of policy measures, although those studies are underway. Until they are completed, it is unwise to take emissions control actions, since we do not know which ones will be effective and what the costs and other impacts of different policies would be.

Additionally, in your question you say that my testimony called Clean Coal technology the solution to the greenhouse effect. That is not what my testimony said. Some of the Clean Coal technologies can play a role in limiting emissions, including CO_2 emissions, by reducing the amounts of hydrocarbon fuel combustion through increased energy efficiency. They are not, however, the only means for moderating or reducing greenhouse gas emissions. My testimony covered many DOE technology programs which can contribute to a solution. Protection of energy security interests of the United States and reducing greenhouse gas emissions will involve a balanced and diverse energy supply and demand profile.

Question 7: The Department is reported to have completed a study on the benefits of carbon dioxide reduction of the Clean Coal Program. Could you outline some of the findings of this study? How do these Clean Coal technologies compare in terms of emissions with other fuel sources such as natural gas or even oil? Do you believe Clean Coal is the answer to the Greenhouse Effect?

Answer: The Department has not completed a study on the possibilities of carbon dioxide reduction by means of the technologies being developed in the Clean Coal Program. However, the Office of Fossil Energy has prepared a brief preliminary overview of the carbon dioxide emissions issue and the possible role that clean coal technologies might have in addressing that issue. This overview was prepared principally as an internal working document to acquaint Department representatives with the interrelationships between coal combustion and carbon dioxide emissions. Although it still considered preliminary and is in draft form, it will be forwarded to you next week to provide some answers to your questions about the impact that advanced coal burning technologies can have in helping to address the Greenhouse Effect.

The comparison of carbon dioxide emissions resulting from the burning of coal, oil, and natural gas, also is discussed in the preliminary overview provided in response to the first part of this question.

Most experts agree that the Greenhouse Effect is a very complex phenomenon impacted by a wide range of interdependent factors. Obviously, the implementation of the Clean Coal Program will not control all of the sources generating gases believed to contribute to this phenomenon. However, the use of the more efficient coal utilization technologies being developed in the Program can help to significantly limit the amount of emissions generated through the use of coal by the electric power generation and industrial sectors.

Question 8a: Is there any way to scrub CO2 out of coal fired power plant emissions?

Answer: Yes. Both dry and wet scrubbing are possible. Two DOE/Carbon Dioxide Research reports have addressed this issue. This analysis suggests that the most economically attractive scrubbing agent would be alkanolamines. Approximately 90 percent of CO2 could be removed from flue gases with currently available technologies. In addition to the CO2 scrubbing, technologies for the subsequent steps of recovery, and disposal have been considered. Removal, recovery, and disposal are estimated to double the cost of generating electric power. At this time, removal and recovery technologies have been technically demonstrated. Disposal technologies in permanent reservoirs have not been demonstrated.

Question 8b: What percentage of greenhouse gases are generated by coal fired plants? By electrical generation?

Answer: Estimates of U.S. CO2 emissions by fuel-use and end-use sector for 1985 are provided in the following table.

CO2 Emissions by Fuel and Sector: 1985
(Peta grams per year)

1985	Oil	Gas	Coal	Total	Percent
Residential/Commercial	0.05	0.10	0.01	0.16	13%
Industrial	0.09	0.09	0.07	0.25	20%
Transportation	0.40	0.01	0.00	0.41	32%
Electric Utilities	0.02	0.05	0.37	0.44	35%
Synfuels	0.00	0.00	0.00	0.00	0%
Venting & Flaring	0.00	0.00	0.00	0.00	0%
Total	0.56	0.25	0.45	1.26	100%

Question 9a: You call for international cooperative policy analysis when "science is sufficiently robust". Please describe for the Committee what is meant by the term "robust".

Answer: In the context of the testimony, "robust" means sufficient scientific understanding and predictive capability to convince various decision makers to take actions which they would not otherwise have taken. What is sufficient will depend on the severity of the threat, its probability, and the cost to avoid it. As this definition is applied to the problem of CO_2 and climate change, the present scientific understanding cannot be regarded as sufficiently robust and, therefore, international cooperative action would be premature because of the uncertainty in regional predictions and in understanding of the basic global climate processes. We cannot yet describe the threat, assess its probability, or calculate the cost to avoid it.

Question 9b: Can we begin cooperative efforts before scientific understanding is completely "mature"?

Answer: Yes. It should be recognized that my prepared testimony described DOE's participation and cooperation in new initiatives, i.e., "an Intergovernmental Panel on Climate Change to advise the World Meteorological Organization and the United Nations Environment Programme." This is an example of a cooperative international initiative, which is progressing as both science and policy developments continue. The degree of completeness of the results from this cooperation will grow as greater maturity of understanding is reached.

Question 9c: At what point will the Department consider our understanding of this issue mature?

Answer: Given the current knowledge base, it is simply not, at this time, possible to state when the "issue will be mature". A problem like CO_2-global climate change has not been encountered before, and there are no established standards for recognizing maturity. Scientists, policy analysts, and decision makers must, therefore, learn together and collectively decide when the degree of understanding that characterizes "maturity" has been reached, as our research, assessments and analyses provide progress.

Question 10: What initiatives does the Department have for working with other nations to share information and technology on this global warming?

Answer: The Department shares information with other nations through formal agreements, such as bilateral protocols, and through less formal scientist-to-scientist cooperation. For example, the Department has a Protocol on Fossil Energy Research with the Peoples Republic of China (PRC). In Annex III of the protocol, four research tasks on the greenhouse issue are included. This research addresses the need for improved climate models, the long-term data to validate the models, and data on the possible emissions from rice paddy fields of methane, another greenhouse gas. The one unique aspect of this particular work involves the development of the climate record from Chinese writings that predates Columbus, and by the use of such data to validate and improve climate models.

An example of how the Department develops and leads in scientist-to-scientist activities is in its strong program of climate model diagnostics, which has the cooperation and participation of the world's principal climate modelers. The objective of the program is to understand the differences among the models and between the models and data. DOE has taken an international lead role:

- in cooperation with the World Meteorological Organization, to compare and evaluate the mathematical scheme used in the climate models to calculate the radiative energy change due to increased CO2;

- to compare mathematical techniques used in the climate models, i.e., by describing the basic equations governing the dynamics of the atmosphere and the ocean system;

- in cooperation with NSF, to develop the data base to be used in the subsequent comparison between the warm climate of 6,000 years ago and the model-calculated climate of 6,000 years ago;

- to compare climate-model-calculated results with the observations of current climate; and,

- to develop and initiate an international intercomparison of climate models.

This latter activity involves virtually all international climate modeling principals. At the recent science team meeting of the group, initial results were discussed on how clouds affect and are effected by climate change. The 24 attendees came from six countries and represented government, university, and private climate model research institutions from Japan, Canada, Britain, Germany, China and the U.S. The intercomparison includes 11 models maintained by scientists at the Canadian Climate Centre, Colorado State University, the Institute for Atmospheric Physics (China), the Lawrence Livermore National Laboratory, the Meteorological Research Institute (Japan), the National Center for Atmospheric Research, the National Oceanic and Atmospheric Administration's (NOAA) Geophysical Fluid Dynamics Laboratory, the NOAA National Meterological Center, Oregon State University, the United Kingdom Meterorological Office, and the University of Hamburg.

Question 11: Given what we know about the potential for reducing CO2 emissions through increased energy efficiency, why have programs for conservation programs been cut so drastically under this Administration? (Especially in the area of residential heating which consumes large quantities of oil, coal, and gas-generated electricity).

Answer: Improvements in energy efficiency offer significant opportunities to control CO2 emissions and research in this area is an important component of the Department's research program. While both Congressional appropriations and program budget requests for conservation R&D have experienced a general reduction in recent years as a result of overall fiscal constraints and the need to more effectively focus the program, promising conservation research in combustion and buildings and community systems has been continued. The budget requests to support the energy conservation R&D programs have trended slightly upward over the last four years.

Over the last several years, the Office of Conservation and Renewable Energy has developed a very effective strategy for program planning and project selection which has received peer review or input from numerous members of the research community, including the National Academies of Science and Engineering, the Energy Research Advisory Board, and industry. The results of this effort are the multi-year plans for the Office of Energy Conservation and the Office of Renewable Energy. These multi-year research plans provide a workable, peer-reviewed approach to prioritizing and selecting projects that best support the national interest. This allows us to target research efforts toward the most productive endeavors and has led to significant successes in areas ranging from superconductivity and high temperature materials to heat pump technologies and window glazings. These plans were forwarded to the Committee earlier this year. We solicit the Committee's advice and comments on these plans and your assistance in using them to assure that every dollar appropriated for conservation R&D is spent productively.

Question 12:	You state on page 10 of your testimony that methanol has the potential for contributing to a decrease in transportation emissions and the use of fossil based fuels. Could you explain methanol's contribution to the reduction of CO_2 emissions.
Answer:	Page 10 of my testimony includes the statement that "methanol ... produced from biomass [has] the potential for reducing transportation emissions and displacing fossil based liquid fuels".

Methanol, commonly known as wood alcohol, offers a number of potential advantages as a transportation fuel. The most significant advantage from a CO_2 perspective is that an integrated wood to methanol fuel cycle would substantially lessen the CO_2 burden. If biomass is grown and harvested specifically as a methanol feedstock, as in short-rotation silviculture plantations, the CO_2 emitted upon combustion can be no more than the carbon absorbed during photosynthesis and fixed into the biomass growth. Thus, the change in atmospheric CO_2 is negligible when the growing, harvesting, and combustion elements are considered. The net effect is a substantial reduction in the rate of increase of CO_2 emissions to the atmosphere that would otherwise be attributable to fossil-based transportation fuels. In this regard, wood-to-methanol fuel can be considered among the least polluting transportation fuels.

Methanol produced from natural gas which would otherwise be flared into the atmosphere would also have a net positive effect to the extent that it would replace petroleum fuels that would otherwise be used.

Question 13: You mention in your prepared statement that caution should be exercised to avoid taking actions which would burden the U.S. economy or any sector in a manner which is unwarranted based on scientific evidence. What burden do you anticipate a global warming and its ambient effects would have on the United States economy? Do you feel conservation and energy efficiency measures, including conservation of fuel through tighter CAFE standards would place an overwhelming strain on the U.S. economy or our nation's international competitiveness? What percentage of greenhouse gases are generated by the transportation sector?

Answer: Based on our present understanding, global climate change and associated impacts, as well as potential response strategies to moderate and reduce emissions and to adapt to the effects of climate change, could impose extremely heavy burdens on the U.S. economy, well beyond costs associated with other air emissions or other pollutants. The degree of cost -- and of potential benefit -- will be a function of the specifics of any measure or set of measures and, hence, cannot be estimated at this time. This applies to conservation and to energy supply measures.

In response to your latter question, the transportation sector contributes 32 percent of the 1985 U.S. CO2 emissions from fossil fuels.

Question 14: In the Department's State-of-the-Art Report on Carbon Dioxide and the Greenhouse Effect, scientists concluded that "human effect on atmospheric composition and the size and operation of the ecosystem may overwhelm the life support system crafted in nature over billions of years." What is your reaction to this statement?

Answer: The context of this statement ("human effect on atmospheric composition and the size and operations of the terrestrial ecosystem represent major excursions that may yet overwhelm the life-support system crafted in nature over billions of years") is a philosophical discussion of the human influence on the planetary life-support system. The State-of-the-Art (SOA) Report (DOE/ER 0239, p. 300) draws on views from Lovelock's Gaia (goddess of the Earth) Hypothesis (Lovelock was a co-author of this chapter). The point of discussion in the SOA is to question whether our life-support system is resilient to human or natural disturbance, or whether humans are able to modify the system through CO2-induced climate change, by modification of air quality, with new pesticides/toxic substances, by erosion/sedimentation/eutrophication, etc. As the SOA points out, we have much to learn about human modification of the environment.

One way of studying the problem is to use reliable global models to test hypotheses and explore different possible outcomes. The SOA's also point out that a knowledge base does not now exist for determining whether operations of ecosystems will be overwhelmed, modified in ways to relax stress, or not affected at all.

Question 15: Would it be possible for the Department to supply approximate state-by-state emissions data for CO_2 and NOx in order to assess each states role and contribution to Greenhouse gases? Do you have studies underway to seek to analyze these figures?

Answer: Two tables are attached with the requested information. The NOx emission estimates are from the NAPAP Interim Assessment, Volume II. The CO_2 estimates are only approximate and were done to meet this request. At this time, the Department does not estimate CO_2 emissions by state on a regular basis. Estimates for other greenhouse gases are not available. Analysis of state emissions have not been carried out by DOE.

Table 1-16.—State-level estimates of man-made NO_x emissions from vehicles, power plants, and all sources in 1975, 1980, and 1985 (million metric tons/yr of NO_2).

STATE	1975			1980			1985[b]		
	HIGHWAY VEHICLES	POWER PLANTS	TOTAL	HIGHWAY VEHICLES	POWER PLANTS	TOTAL[a]	HIGHWAY VEHICLES	POWER PLANTS	TOTAL
Alabama	0.14	0.14	0.41	0.14	0.16	0.42	0.13	0.17	0.42
Arizona	0.09	0.03	0.18	0.10	0.08	0.23	0.09	0.11	0.25
Arkansas	0.09	0.01	0.16	0.09	0.03	0.18	0.09	0.09	0.24
California	0.72	0.08	1.18	0.72	0.09	1.21	0.68	0.07	1.11
Colorado	0.08	0.06	0.24	0.09	0.09	0.26	0.08	0.11	0.28
Connecticut	0.09	0.03	0.13	0.08	0.02	0.13	0.08	0.02	0.12
Delaware	0.02	0.02	0.06	0.02	0.01	0.06	0.02	0.03	0.06
D.C.	0.02	~0	0.03	0.02	~0	0.02	0.01	0	0.02
Florida	0.30	0.19	0.63	0.29	0.22	0.65	0.27	0.25	0.66
Georgia	0.19	0.12	0.43	0.20	0.21	0.53	0.19	0.28	0.58
Idaho	0.03	~0	0.08	0.04	~0	0.08	0.03	0	0.08
Illinois	0.32	0.32	0.86	0.32	0.33	0.88	0.30	0.29	0.81
Indiana	0.20	0.30	0.66	0.20	0.32	0.68	0.19	0.36	0.71
Iowa	0.11	0.06	0.24	0.12	0.09	0.27	0.11	0.11	0.28
Kansas	0.10	0.06	0.40	0.10	0.09	0.42	0.10	0.10	0.40
Kentucky	0.13	0.24	0.52	0.14	0.25	0.56	0.13	0.27	0.58
Louisiana	0.14	0.08	0.62	0.14	0.10	0.61	0.13	0.14	0.60
Maine	0.03	~0	0.06	0.03	~0	0.06	0.03	~0	0.05
Maryland	0.12	0.05	0.22	0.12	0.06	0.23	0.11	0.07	0.19
Massachusetts	0.14	0.06	0.25	0.14	0.06	0.25	0.13	0.08	0.26
Michigan	0.26	0.23	0.64	0.26	0.23	0.63	0.24	0.24	0.62
Minnesota	0.15	0.09	0.31	0.15	0.10	0.33	0.14	0.09	0.30
Mississippi	0.09	0.03	0.23	0.09	0.05	0.25	0.09	0.05	0.23
Missouri	0.18	0.18	0.45	0.19	0.22	0.49	0.17	0.20	0.45
Montana	0.04	0.01	0.10	0.04	0.02	0.12	0.04	0.03	0.13
Nebraska	0.07	0.03	0.14	0.07	0.04	0.16	0.07	0.04	0.15
Nevada	0.03	0.04	0.08	0.03	0.04	0.09	0.03	0.05	0.10
New Hampshire	0.02	0.02	0.05	0.02	0.02	0.05	0.02	0.02	0.05
New Jersey	0.21	0.06	0.48	0.20	0.07	0.46	0.19	0.06	0.41
New Mexico	0.05	0.06	0.20	0.05	0.08	0.22	0.05	0.09	0.22
New York	0.34	0.14	0.72	0.33	0.14	0.68	0.30	0.14	0.65
North Carolina	0.19	0.15	0.42	0.19	0.20	0.47	0.18	0.17	0.42
North Dakota	0.03	0.03	0.08	0.04	0.06	0.12	0.03	0.09	0.15
Ohio	0.34	0.47	1.06	0.34	0.47	1.06	0.32	0.46	1.02
Oklahoma	0.13	0.07	0.34	0.13	0.10	0.37	0.12	0.13	0.37
Oregon	0.10	~0	0.20	0.10	~0	0.22	0.10	~0	0.21
Pennsylvania	0.32	0.31	0.85	0.32	0.36	0.90	0.30	0.34	0.86
Rhode Island	0.02	~0	0.03	0.02	~0	0.03	0.02	~0	0.03
South Carolina	0.11	0.05	0.21	0.11	0.08	0.24	0.10	0.07	0.24
South Dakota	0.03	0.02	0.06	0.04	0.02	0.07	0.03	0.02	0.07
Tennessee	0.16	0.19	0.45	0.17	0.19	0.47	0.16	0.18	0.45
Texas	0.56	0.32	2.45	0.59	0.49	2.51	0.55	0.61	2.47
Utah	0.04	0.02	0.11	0.04	0.03	0.13	0.04	0.04	0.13
Vermont	0.03	~0	0.03	0.03	~0	0.04	0.03	~0	0.03
Virginia	0.17	0.06	0.34	0.17	0.06	0.33	0.16	0.06	0.32
Washington	0.14	0.03	0.25	0.14	0.03	0.27	0.13	0.04	0.25
West Virginia	0.06	0.27	0.38	0.06	0.27	0.40	0.06	0.29	0.42
Wisconsin	0.15	0.10	0.34	0.15	0.12	0.36	0.15	0.14	0.38
Wyoming	0.03	0.04	0.17	0.04	0.10	0.21	0.03	0.13	0.25
Total U.S.[c]	7.10	4.78	18.5	7.21	5.81	19.4	6.79	6.34	19.1

[a] Total U.S. emissions for 1980 presented here are about 1.3 million metric tons lower than those in the 1980 NAPAP Emissions Inventory (Wagner et al., 1986), primarily due to the possible omission of emissions from combustion of nonpurchased fuels in the industrial sector and exclusion of emissions from forest fires and similar burning.

[b] Values for 1985 are presented for power plants. These were calculated using the same methodology as in Knudson, 1986. Vehicle emissions presented are for 1984. The totals presented are the sum of the 1985 power plant emissions and 1984 values for other sources. They do not reflect changes in emissions from nonutility sources estimated by EPA to have occurred from 1984 to 1985.

[c] Values may not sum to totals due to independent rounding.

Source: Knudson, 1986.

"CO_2 EMISSIONS BY STATE"

STATE	Percent* From Coal	Percent From Gas	Percent From Petrol.	Percent of Total Fossil Fuel
Alabama	3.8	1.3	1.5	2.2
Alaska	-	1.2	0.7	0.1
Arizona	2.0	0.8	1.0	1.3
Arkansas	1.3	1.1	1.0	1.1
California	0.3	10.6	10.0	6.9
Colorado	1.7	1.3	1.1	1.3
Connecticut	0.1	0.5	1.4	0.8
Delaware	0.4	0.2	0.4	0.4
Dist. of Col.	-	0.2	0.1	0.1
Florida	2.7	1.7	4.2	3.2
Georgia	4.2	1.6	2.4	2.8
Hawaii	-	-	0.7	0.4
Idaho	0.1	0.2	0.3	0.2
Illinois	4.6	5.5	3.7	4.3
Indiana	6.8	2.4	2.4	3.9
Iowa	1.5	1.3	1.1	1.3
Kansas	1.5	2.0	1.3	1.5
Kentucky	4.1	1.0	1.5	2.3
Louisiana	0.9	8.1	4.4	4.0
Maine	-	-	0.6	0.3
Maryland	1.5	0.9	1.5	1.4
Massachusetts	0.6	1.3	2.5	1.6
Michigan	4.5	4.2	2.8	3.6
Minnesota	1.3	1.5	1.6	1.5
Mississippi	0.6	1.3	1.1	1.0
Missouri	3.0	1.5	1.9	2.2
Montana	0.6	0.3	0.5	0.5
Nebraska	0.7	0.7	0.6	0.7
Nevada	0.7	0.2	0.4	0.5
New Hampshire	0.2	0.1	0.4	0.3
New Jersey	0.6	2.2	3.9	2.5
New Mexico	1.5	0.9	0.7	1.0
New York	1.7	4.5	5.2	3.9
North Carolina	3.2	0.8	2.2	2.2
North Dakota	1.8	0.2	0.4	0.8
Ohio	8.0	4.3	3.7	5.2
Oklahoma	1.4	3.4	1.5	1.8
Oregon	0.1	0.5	1.0	0.6
Pennsylvania	7.8	3.7	3.9	5.1
Rhode Island	-	0.2	0.4	0.2
South Carolina	1.5	0.6	1.1	1.1
South Dakota	0.2	0.1	0.3	0.2
Tennessee	3.4	1.1	1.8	2.2

STATE	Percent* From Coal	Percent From Gas	Percent From Petrol.	Percent of Total Fossil Fuel
Texas	6.7	19.7	13.3	12.3
Utah	1.2	0.7	0.6	0.8
Vermont	-	-	0.2	0.1
Virginia	1.7	0.8	2.2	1.8
Washington	0.5	0.8	1.9	1.2
West Virginia	5.0	0.7	0.8	2.2
Wisconsin	2.1	1.7	1.5	1.7
Wyoming	2.3	0.5	0.4	1.1

* The entry for each state is the approximate percentage of CO_2 emitted in that state for that fuel category compared to the national total of CO_2 emitted for that fuel category. An entry of "-" is less than 0.05 percent of the national total.

NOTE: Percentages are slightly inaccurate for petroleum, since lubricants and feedstocks were included but not necessarily consumed in the originating state.

Question 16: Has the Department examined programs to limit methane emissions and utilize them? For example, feedlots, landfills, and sewage treatment facilities all generate methane that is released directly into the atmosphere. Could this methane be used to generate heat or electricity?

Answer: The Department has conducted research in the production and recovery of methane from feedlot and other manure wastes, landfills and sewage treatment facilities. Fundamentally, anaerobic digestion converts the natural organic materials to biogas, a mixture of methane, which is the principal ingredient of natural gas, and carbon dioxide. Biogas is used for boiler fuel and as a fuel for stationary engine/electric generation sets. With the carbon dioxide removed, it is used as natural gas or as a mobile engine fuel. Feedlot waste biogas, landfill gas and sewer gas recovery are now commercial technologies that can continue to grow without Federal support. The use of feedlot wastes to produce usable methane is relatively new and principally driven by the economics of the acceptable environmental disposal of manure. The first landfill gas recovery unit began operation in 1975. Federal research since then has helped the industry to understand the mechanisms of landfill gas production, recovery and conversion to energy. Today there are over 100 landfills from which the gas is recovered to produce electricity, heat and natural gas. This industry is continually expanding. Finally, anaerobic digestion has been used principally to stabilize and reduce the volume of sewage sludge since 1895. The methane has been used productively since the 1920's. Over one-half of the sewage treatment plants in the United States have anaerobic digesters producing methane. However, low energy prices and increasing availability of natural gas has prevented widespread use of the methane produced but none is released to the atmosphere. At worst, it is burned in a flare. Flaring, of course, converts methane to CO2 and water.

Question 17: Is the flaring of natural gas, worldwide, a significant contributor to the Greenhouse Effect?

Answer: No. natural gas flaring is a relatively small contributor to global CO2 emissions. It accounts for approximately 2 percent of fossil fuel CO2 emissions would wide.

Question 17a: If so, could methanol production or other use of this gas significantly reduce net CO2 emissions?

Answer: The production of methanol from gas that would have been either vented or flared would not significantly reduce CO2 emissions, although taking energy that would have been used without purpose and changing it from a wasted from to a useful one would, of course, replace some amount of energy that would have other wise been required to be used.

Question 18a: The Department has suggested that negative feedback in the climate system may mitigate the Greenhouse Effect. Are you aware of positive feedback?

Answer: Global climate constitutes a complex system with many feedbacks, linkages, and interacting process. While feedbacks may be either positive or negative, their form and magnitude are often poorly understood. For example, clouds may either enhance or counteract the greenhouse warming; however, the rudimentary way in which clouds are included in the climate models makes it difficult to determine if clouds function as a negative or as a positive feedback on climate change. Warming of the ocean can enhance the uptake of CO2 through increased biological productivity (a negative feedback on atmospheric CO2), but too much warming, (and "too much" cannot yet be defined,) may decrease biological productivity and decrease the uptake of CO2 (a positive feedback).

Question 18b: What about CO2 increases from forest dieback resulting from climate change?

Answer: Increased CO2 from forest dieback is speculative as a positive feedback because it is unclear whether forest growth will be enhanced or lessened by increased atmospheric CO2 and climate change. More CO2 stimulates growth and alleviates stress, which conceivably could mitigate dieback, irrespective of cause.

Question 18c: Are you confident that these or other possible feedbacks don't cancel the effects of negative feedback?

Answer: Other positive feedbacks may also be postulated such as enhanced CO2 flux from the oceans as the water warms, causing ocean chemistry and circulation to change. Carbon dioxide and methane flux from the tundra ecosystem to the atmosphere may increase if temperature increases. There is the potential for many small and a few large positive and negative feedbacks; however, scientific understanding is currently inadequate when it comes to allowing us to know which ones may predominate of whether a given feedback may cancel another one.

Question 19:	Do you agree with Dr. Hansen's recent statement to the Committee that "the global warming is now sufficiently large that we can ascribe with a high degree of confidence a cause and effect relationship to the Greenhouse Effect"?
Answer:	Dr. Hansen's statement that the recent warming can be attributed to the Greenhouse Effect is not universally supported by the scientific community. Certainly the recent warming is in the direction that the greenhouse theory would suggest. However, the warmer-than-average years remain within the range of natural variability.

Dr. Hansen has analyzed the results of only one model. The differences among climate models at continental or smaller regions make it impossible to see whether the predicted rate, magnitude, and regional pattern of the recent warming is consistent with the observations. As officials from the National Oceanic and Atmospheric Administration stated before Senator Stafford:

> A comprehensive "fingerprint" study is required to assess the probability that recent changes in various fields of climate elements are indicative of a carbon dioxide-rich atmosphere.

DOE concludes that it is premature to assign cause and effect to the recent warming relative to increased greenhouse gases.

Department of Energy
Washington, DC 20585

October 14, 1988

Honorable J. Bennett Johnston
Chairman
Committee on Energy and Natural
  Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

On August 11, 1988, Undersecretary Donna R. Fitzpatrick appeared before your committee to discuss global climate change. Following that hearing, you submitted written questions for our response to supplement the record. The answers to those questions were provided to you October 7. Our response to question 7 indicated that a copy of a draft overview of the carbon dioxide emissions issue would be forwarded to you this week. Enclosed is that overview.

If you have any questions, please have your staff call Rebecca Thompson on 586-4277. She will be happy to assist.

Sincerely,

Rebecca A. Thompson
for Robert G. Rabben
Assistant General Counsel
  for Legislation

Enclosure

cc:
Honorable James A. McClure
Ranking Minority Member

TABLE

CARBON DIOXIDE EMISSIONS FROM FOSSIL FUELED FACILITIES

Technology	Fuel	Efficiency (approx.)	Total CO2 (Million tons/year)	%Change
Conventional Pulverized Coal (w/o FGD)	Coal	35%	2.75	---
Conventional Pulverized Coal (w/FGD)	Coal	34%	2.83	+3%
Atmospheric Fluidized Bed Combustion	Coal	36%	Essentially no change	0
Pressurized Fluidized Bed Combustion	Coal	40%	2.48	-10%
Integrated Gasification Combined Cycle (IGCC)	Coal	42%	2.36	-14%
IGCC w/Fuel Cell	Coal	50%	1.98	-28%
Conventional Combustion w/Advanced Flue Gas Cleaning	Coal	35%	Essentially no change	0
Advanced Cleaning	Coal	36%	Essentially no change	0
MHD	Coal	55%	1.80	-34%
MHD	Natural Gas	50%	1.19	-57%
Turbine Combined Cycle	Natural Gas	47%	1.27	-54%
Fuel Cell	Natural Gas	55%	1.09	-60%

Assumptions: 2.8% sulfur coal, 11,600 BTU/lb
65% Capacity Factor
Nominal 500 MWe Electric Power Plant
90% sulfur removal (where required)

Question 7: **The Department is reported to have completed a study on the benefits of carbon dioxide reduction of the Clean Coal Program. Could you outline some of the findings of this study? How do these Clean Coal technologies compare in terms of emissions with other fuel sources such as natural gas or even oil? Do you believe Clean Coal is the answer to the Greenhouse Effect?**

Answer: The Department has not completed a study on the possibilities of carbon dioxide reduction by means of the technologies being developed in the Clean Coal Program. However, the Office of Fossil Energy has prepared a brief preliminary overview of the carbon dioxide emissions issue and the possible role that clean coal technologies might have in addressing that issue. This overview was prepared principally as an internal working document to acquaint Department representatives with the interrelationships between coal combustion and carbon dioxide emissions. Although it still considered preliminary and is in draft form, it will be forwarded to you next week to provide some answers to your questions about the impact that advanced coal burning technologies can have in helping to address the Greenhouse Effect.

The comparison of carbon dioxide emissions resulting from the burning of coal, oil, and natural gas, also is discussed in the preliminary overview provided in response to the first part of this question.

Most experts agree that the Greenhouse Effect is a very complex phenomenon impacted by a wide range of interdependent factors. Obviously, the implementation of the Clean Coal Program will not control all of the sources generating gases believed to contribute to this phenomenon. However, the use of the more efficient coal utilization technologies being developed in the Program can help to significantly limit the amount of emissions generated through the use of coal by the electric power generation and industrial sectors.

APPENDIX II

Additional Material Submitted for the Record

STATEMENT OF THE
JEWISH NATIONAL FUND OF AMERICA

Committee on Energy and Natural Resources
United States Senate

Hearing on the Relationship of Deforestation and Development Policies to Global Atmospheric Change

September 20, 1988

The Jewish National Fund of America is happy to have the opportunity to express to the Committee its support of the National Energy Policy Act of 1988 and the bill's goals of reducing the generation of carbon dioxide and trace gases in order to deter atmospheric warming and global climate change. Though the bill is considered a "national" energy policy, it is necessarily designed to slow climate change throughout the world. Without the international cooperation called for in the bill, U.S. domestic atmospheric policies are limited.

It is in that light that the Jewish National Fund wishes to express its sentiments towards and support of your present legislation. We are particularly drawn to Title XIV of the bill entitled "Development Assistance." This title directs investigation and inventory of forest plans in tropical countries throughout the world. Upon the conclusion of data collection, appropriate agencies would be designated to create incentives for tropical countries to encourage afforestation and disincentives to discourage deforestation. Such an incentive/disincentive program speaks directly to the heart and soul of our afforestation efforts in Israel over the past 80 years.

Trees are the guardians of the earth. They cleanse the air of pollution, fortify the soil with vital nutrients, suppress noise and dust and provide areas for peaceful recreation. For over 80 years, our afforestation efforts in Israel have resulted in increasing the quality of life not only of Israelis, but of peoples all over the world through the ecological benefits that are a direct result of afforestation.

The Jewish National Fund of America (JNF) and its counterpart in Israel, Keren Kayemeth LeIsrael, are the organizations responsible for afforestation and land reclamation in Israel. Since 1901, the JNF has transformed a once-barren land into a nation of thriving forests, agricultural communities, parks and industrial areas. The JNF has planted over 180 million trees, creating 280 forests which cover 275,000 acres in Israel in addition to reclaiming close to 300,000 acres of difficult terrain for farming, housing and industry. Furthermore, in cooperation with numerous research and development programs within government and university institutions, the JNF has sponsored projects to help diversify crops grown in arid regions, as well as monitoring the growth and adaptability of over 400 species of local and foreign trees and shrubs originating in different arid zone regions around the world.

It is out of concern for the afforestation of arid regions that the Jewish National Fund is appealing to the distinguished Committee members. Though more than 180 million trees have already been planted, over 75% of the Israeli landscape remains stark. The Galilee, the Judean Hills and the Negev are all regions of ancient Jewish homeland that were neglected for 2,000 years. Every settlement, kibbutz, town, or city grows and develops by planting trees--this is a fact of life in Israel and characteristic of every other arid nation in the world.

By expanding Title XIV of S. 2667 to include arid regions of the world, you provide foreign governments and environmental organizations like ourselves with the opportunity to ensure the success of your legislation. In many tropical countries of the world, trees are being needlessly destroyed to profit from the wood products they produce. For these situations, you wish to secure disincentives. In our case, disincentives designed to prevent forest depletion would not be an issue.

We ask that arid regions be included along with tropical countries in your evaluation programs and in the incentives you offer them. We wish to work with you in your efforts to better the environment through a reduction of global warmth effects. After all, serious global warming effects would act more quickly in devastating an already arid land than it would in a tropical forest.

The Jewish National Fund applauds the Committee's use of incentives and disincentives to encourage afforestation. In order to deal with the "greenhouse effect," international cooperation is needed of *all* countries. It comes as no surprise that the United States is once again paving the path to international cooperation. The Jewish National Fund of America would be pleased to offer assistance to the Committee in any way it can to further its efforts, particularly in promoting forestry plans in developing countries with similar climatical characteristics to Israel.

We believe that through international cooperation, especially in the areas of afforestation, tree research and arid land development, progress towards the mitigation of the worsening effects of global climate change can be made. The authors of this bill have had the foresight to develop a global solution to a global problem. Our experience in Israel, in reclaiming the desert and making it come alive in green, is the world's to adopt, and we look forward to working with the Committee in the future in implementing its well-suited policy.

EIR

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SENATE ENERGY AND NATURAL RESOURCES COMMITTEE

Hearing on the

Greenhouse Effect and Global Deforestation

September 20, 1988

By Rogelio Maduro

for the

Executive Intelligence Review

Thank you Mr. Chairman for the opportunity to testify on the "Greenhouse Effect" and global deforestation.

Rogelio A. Maduro

RAZING OF RAINFORESTS UPSETS WORLD CLIMATE

This is the first in a series of Executive Intelligence Review reports in preparation, which will deal with various aspects of the present, aberrant weather patterns worldwide. What this first report should make clear, is the nature of the fraud being perpetrated by the coterie of malthusians who argue that the drought is a by-product of industrial development. We are hearing a great deal about the supposed ``greenhouse effect'' lately; which, it is claimed, is caused by industrial emissions mainly of carbon by-products. What is not mentioned is the fact that an amount vastly greater than all the industrial pollution of the atmosphere by the United States, is released by the wanton burning of the Brazilian rain forest. The full consequences of the ongoing destruction of our rain forests are as yet incalculable.

On August 24, 1987, the NOAA-9 meteorological satellite flew its usual course over the Brazilian Amazon, a routine overflight, except that this day and for the next several weeks, its data was being monitored for the first time to detect large burnings of biomass in the Amazon. The picture was rather frightening: 8,000 square kilometers (3,089 square miles) of land were on fire from 6,800 separate fires, none less than a square kilometer and several over 10 square kilometers in dimension. These were not accidental fires. They were set by man.

At the end of the satellite study, led by Brazilian scientist Alberto W. Setzer of the Institute for Space Studies in S;atao Paulo, it was conservatively estimated, based on the satellite images and corroborated by overflight and on-site inspection, that over 20 million hectares (200,000 square kilometers, or 77,220 square miles) of land were burned down in 1987 in the Amazon Basin alone (see Map 1). Of this, at least 40% corresponded to virgin forest.

As can be seen in Table 1, the satellite pictures revealed that that approximately 4.4% of the land area of the Amazon Basin was burned down last year; at the state level, the percentage of area burned in relation to the area of the state varied from 18.7% in Rondonia to 0.1% in Amazonas.

In an interview with EIR from Sao Jose Dos Campos in Brazil, Alberto Setzer stated that based on real time data the Brazilian Space Center is presently receiving from the Satellite, there has been a 30 percent increase in the amounts of burning this year, and they expect that more than 95,000 square miles of land will have been burnt this year by the end of the dry season. This is an area larger than West Germany, and almost as large as the nations of Guyana or Suriname, just north of Brazil (see map), combined. The shaded area of Map 1 corresponds to the Amazon Basin, the only area of Brazil surveyed under the satellite study.

The burnings in the Amazon Basin produced dense smoke clouds over areas of 1.5 million square kilometers. "The smoke from the fires is thick enough to close down large and small airports for weeks, and it certainly increases the number of cases of respiratory illness in the area, but there are no official statistics,'' says Dr. Setzer.

Utilizing standard equations to calculate areas of damage due to nuclear explosives, it can be estimated that between 760 and 815 one-megaton hydrogen bombs, such as those carried in Soviet intermediate range ballistic missiles, would have been required to wreak similar devastation to over 95,000 square miles of Amazon jungle. A one-megaton H-bomb will destroy everything in a radius of approximately 10 kilometers from the point of impact, depending on the topography and altitude at which the bomb detonates. The main difference between burning large areas of rain forest at once and a thermonuclear strike, is that an H-bomb would lift a somewhat larger amount of debris higher up into the atmosphere, and of course, leave a large amount of radioactivity behind. On-site observers remark that after a firestorm, the burnt Amazon forest looks just like Hiroshima or Nagasaki.

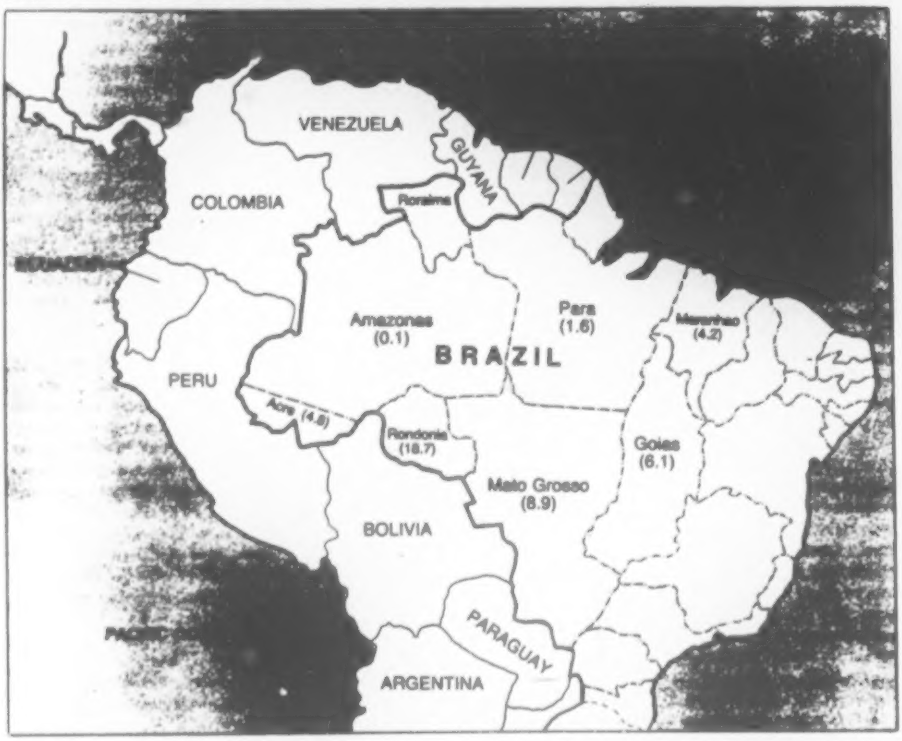
The preceding facts have barely received notice in the press, despite the fact that one of the most severe droughts in history has just devastated food production in the U.S. grain belt. Weather anomalies, from severe drought to flooding, have been multipliying throughout the world in the past few years.

What actual phenomenon in the biosphere has caused these disturbances in the climate is a subject of great debate in the scientific community. However, if one surveys the rain forests of the world, the picture is one of ecological holocaust whose global implications are to be dreaded. Table 2 summarizes the results of the only systematic study done to date on global deforestation. Based on Landsat pictures, the data indicates that the world's rain forests were being deforested at a rate of 11.3 million hectares a year in 1981. That rate has increased exponentially. The NOAA-9 satellite observations revealed that in Brazil, no less than 8 million hectares of land were deforested last year, just in the Amazon, nearly equal to the total amount deforested in the entire

MAP 1

Amazon Basin area covered by satellite study

(Percent of area burned shown in parentheses)


VENEZUELA
GUYANA
Roraima
COLOMBIA
ECUADOR
Amazonas
(0.1)
Para
(1.6)
Maranhao
(4.2)
BRAZIL
PERU
Acre (4.8)
Rondonia
(18.7)
Goias
(6.1)
Mato Grosso
(8.9)
BOLIVIA
PARAGUAY
PACIFIC
ARGENTINA

Shaded area represents the Amazon Basin, the area of Brazil that was under real time observation by the NOAA-9 meteorological satellite. The percentages of landcover area of individual states observed under fire last year by the satellite are in parentheses. For comparison, the total area of land burned in the Amazonas last year is larger than the total area of either Surinam or Guyana, just to the north of Brazil.

TABLE 1

Estimated areas burned in Brazil's Amazonian Basin, 1987

State	Area burnt (km²)	% of state area
Rondonia	45,452	18.7
Mato Grosso	78,718	8.9
Goias	38,910	6.1
Acre	7,274	4.8
Maranhao	13,796	4.2
Para	19,386	1.6
Amazonas	1,093	0.1
Total	204,608	4.4

Source: Alberto Setzer, Relatorio de Atividades do Projecto IBDF-INPE "SEQE"-Ano 1987

TABLE 2

Annual rates of deforestation (1980)

(thousand hectares)

Region	Annual rates of deforestation Tree formations: Closed	Open	All
Tropical America (23 countries)	4,339	1,272	5,611
Tropical Africa (37 countries)	1,331	2,345	3,676
Tropical Asia (16 countries)	1,826	190	2,016
Total (76 countries)	7,496	3,807	11,303

Source: Jean Paul Lanley, "Tropical Forest Resources," U.N. Food and Agricultural Organization, Forestry Paper 30, Rome: FAO, 1982.

TABLE 3

The world's principal tropical forest countries by area

(square kilometers)

Country	National area	Undisturbed forest	Legal/managed forest	Unproductive forest	Total forest area	% world total
Brazil	8,511,965	2,886,300	120,000	556,500	3,562,800	30.68
Indonesia	1,903,650	389,150	346,600	400,000	1,136,750	9.78
Zaire	2,345,409	797,400	3,800	255,300	1,056,500	9.09
Peru	1,285,215	373,200	60,000	259,900	693,100	5.97
Colombia	1,138,914	386,000	9,000	69,000	464,000	3.99
India	3,166,828	48,850	334,730	76,860	460,440	3.96
Bolivia	1,098,580	177,600	120,900	141,600	440,100	3.79
Papua New Guinea	475,300	138,150	2,200	196,750	337,100	2.90
Venezuela	912,050	76,000	116,100	126,600	318,700	2.74
Burma	676,030	141,070	90,090	80,770	311,930	2.68
Cumulative total		5,413,720	1,203,420	2,163,290	8,780,430	75.62
And 63 other countries		1,270,430	720,350	838,550	2,829,930	24.38
World total		6,684,150	1,923,770	3,001,830	11,610,360	100.00

Sources: Forest types and area from *Tropical Resources Assessment Project*, Rome: FAO, 1981. Country areas from John Paxton, ed., *The Statesman's Yearbook, 1983-84*, London: Macmillan, 1985.

TABLE 4

Regional estimates of emissions produced by burning, 1987

(million metric tons)

Substance	Burning rain forest*	Total U.S. pollutants 1985**
CO^2	518	—
CO	44.03	60.96
POC (particulate organic Carbon)	4.09	—
EC (elemental C)	1.14	—
NOx	1.09	19.23
NH^3	0.48	—
SO	0.17	21.23
K	0.17	—
TPM (total particulate matter	6.22	6.71
O^3	2.49	—
CH^4	4.86	—
CH^3Cl	0.012	—

*Source: Alberto Setzer, Relatorio de Atividades do Projecto IBDF-INPE "SEQE"-Ano 1987

**U.S. Environmental Protection Agency, *National Air Pollutant Estimates, 1940-1986* world in 1981.

Every year, about 6 million hectares of land are irretrievably lost to desertification, and a further 21 million hectares are so degraded that crop production becomes uneconomical. About 3,500 million hectares of land--an area the size of North and South America combined--are affected by desertification, while the rural population affected by serious desertification rose from 57 million people in 1977 to 135 million people in 1984.

The `greenhouse' myth

While this real catastrophe is staring at humanity, the Western news media have been filled with scare stories about the so-called "greenhouse effect.'' The Earth is supposed to warm up several degrees, the polar icecaps melt and submerge a large portion of the Earth's cities, while other major changes ocurr in local climates. The drought that has wiped out a large portion of this year's food production in the United States has been blamed on the "greenhouse effect.''

The scientific evidence behind the "greenhouse theory'' is quite inconclusive, but that is not what is important. What is important is what the proponents of the theory, the news media, and supranational institutions are covering up: the massive, wholesale destruction of the world's rain forest; the rapid increase of global desertification; and the outbreak of pandemic diseases and plagues throughout devastated areas of the underdeveloped sector. Largely as a result of this, and not any so-called "greenhouse effect,'' major anomalies in weather patterns such as this year's drought, are occurring throughout the world, posing serious threats to the world's food supplies and long-term survival of the human race as a whole.

Supporters of the greenhouse theory, including many members of the U.S. Congress, are marshaling forces to implement draconian measures throughout the world that will "save humanity from the greenhouse effect.'' This includes a 50% cutback in the consumption of fossil fuels, extensive measures to control population growth, severe restriction on industrial activities, and ultimately, the creation of a one-world fascist government that will control and "preserve'' all natural resources.

An economic policy

It is the policies of "appropriate technologies'' and IMF and World Bank-dictated "conditionalities'' that are directly responsible for the present rates of deforestation and desertification. U.S. presidential candidate Lyndon LaRouche warned recently:

"It must be emphasized that the deforestation of the Amazon region was a direct result of OECD nations' Brazil policies of the 1960s and 1970s. Not only the notorious Professor Milton Friedman, but also leading social-democratic ideologues among Keynesian economists, such as the late Professor Abba Lerner, proposed that forms of austerity modeled upon those of Germany's Hjalmar Schacht, be imposed upon Brazil, as also upon Chile and other nations. In the case of Brazil, such policy-recommendations were dictated as international financiers' `conditionalities,' as an alternative to Brazil's nuclear energy program, in particular, and to Brazil's big infrastructural projects program in general.

"The use of `biomass' for fuel, as a substitute for coal, petroleum, major hydroelectric projects, and nuclear energy, was key to the process. In addition to the general waste of `biomass' as a substitute for fuel, agricultural projects in the rain forest region were launched on a large scale--with the foreseeable result of transforming land into ruined laterite.

"The Brazil model merely exemplifies the more general result of combining the looting of primary resources, by Lombard-style usury, by the added imposition of both `conditionalities,' and by so-called `environmentalist' anti-technology measures, which has put most of our planet through a downward spiral of economic and ecological devolution.''

Enter the multinationals

The rate of burning of the Amazon rain forest has increased dramatically since 1985, following the opening of penetration roads into previously virgin territory, especially in the states of Rondonia and Mato Grosso. Between 1966 and 1975, 11.5 million hectares of forest were cleared, while the total amount last year alone was 20 million hectares. Despite the common misconception that most of the burning is done by peasants and Indians, during the 10 years up to 1975, 60% of the clearance was done by highway developers (3,075,000 hectares) and cattle ranchers (3,685,271 hectares), and only 17.6% by peasants.

These ratios have shifted since 1975, to the point that today transnational corporations account for almost the entire devastation.

Transnational corporations and European noble families or their "fondi,'' such as the Thurn und Taxis and Matarazzo families, bought most of the Amazon rain forest wholesale in the 1970s and early 1980s, when the Brazilian government sold plots larger than 2,000 hectares for $5 per hectare. The price per hectare rose to $35 in the 1980s, as the Brazilian government started running out of land to sell.

One of the few such transactions that came to public attention was Daniel K. Ludwig's billion-dollar Jari scheme near the mouth of the Amazon. Ludwig purchased 15,000 square kilometers of land (an area larger than the state of Connecticut), and then proceeded to fell and burn the rain forest in an area of 1,000 square kilometers in order to plant two different species of trees. As in all attempts at monoculture in the rain forest, the scheme failed miserably, leaving the Brazilian government with all the debts and a huge patch of desert.

The standard operating procedure in these vast tracts of land is for the transnational corporations, such as Volkswagen, Atlantic Richfield Corporation (ARCO), Goodyear, Nestle, Borden, Kennecot Copper, and Liquigas, to clear-fell the forest, sell the few trees worth the trouble of extracting, and burn the rest; then sow grass and bring in cattle, despite the fact that the land has proven able to sustain only about one head per 10 hectares on average, and that the average life of each ranch is a mere two to seven years before it has to be abandoned due the invasion of toxic weeds, erosion, and loss of nutrients.

ARCO, by the way, is headed by Robert O. Anderson, one of the funders of the world's ``environmentalist'' movement!

Raising cattle in the Amazon is a money losing proposition. The corporations don't intend to produce beef, their enourmous profits are made in land speculation and huge government subsidies, tax-writeoffs and import duty exemptions. What it boils down to is this. In order to pay the foreign debt and fullfill the International Monetary Fund's conditionalities, Brazil has agreed to take an enourmous internal loss, in order to maximize the export of cattle and cash crops that bring in foreign exchange, so they can pay the interest on the debt.

At the same time the rainforest is torn down, a large amount of Brazil's rich and productive farmland, located largely in the south, is today used to grow sugar cane for the production of ethanol. The ethanol is mixed with gasoline, making gasohol, the fuel used by all cars in Brazil.

In the 1970s, the Brazilian government, with financial backing from the World Bank, started an ambitious program to "settle'' the Amazonia, both to quiet the clamor for land reform, and to populate the areas that the transnationals wished to exploit. Land was given free to settlers, and wave after wave of immigrants arrived, enticed by hopes of a new life on their own property. The government, however, did not provide any agricultural machinery, technologies, or infrastructure--not even hospitals, schools, or the most basic services. The settlers were thus forced to use the most primitive slash-and-burn techniques to try to eke out a bare subsistence. Most failed because of the poor soil, and many ended up as laborers on the ranches that mushroomed up. Several hundred thousand of these colonists are now "trapped'' in the Amazon, suffering some of the highest mortality rates in the world due to disease and malnutrition. They work on on the ranches as virtual slaves.

The cost in human lives is enourmous. In the state of Rondonia, in the Western part of Brazil, bordering Bolivia, an explosion of epidemic diseases is ocurring. More than 228,000 cases of virulent strains of malaria have been officially registred, more than one quarter of the population of the state. The settlers are part of the World Bank's Polonoroeste project. Nearly all the money--half a billion dollars--was spent on a super-highway leading 900 miles into the Amazon rainforest, and then the World Bank ran out of money to build sanitary facilities. In the 1960's only 11,000 people inhabited Rondonia, making a miserable living, but since 1980, the World Bank's resettlement program brought more than a million people to settle the rainforest. Disease is rampant throughout Brazil directly as a result of these "resettlement" programs, and the savage austerity cutbacks in health and sanitation imposed upon Brazil by World Bank and IMF conditionalities. An outbreak of dengue fever which infected over a million people in Brazil in 1985, was traced to settlers returning from the failed projects in the Amazon. Other exotic and deadly diseases present in the Amazon, but never seen elsewhere, are now spreading. Malaria, almost eradicated in 1975 as a result of an intensive DDT spraying campaign, now affects over 480,000 Brazilians, representing 50% of all cases in Ibero America; Leprosy has striken 236,000, 85% of all cases in Ibero America, 8 million have Chagas disease, 12 million have schistomiasis. The bubonic plague is erupting at several localities in Brazil, such as the state of Paraiba, where 305 cases were officialy reported last year. Over seventy million Brazilians, out of a population of 140 million, suffer from chronic malnutrition, and on average 40 Brazilian children die every hour.

A previously unknown strain of deadly hepatitis is ravaging the cities of Brazil's Western Amazon in the region of the Purus river. Popularly called "Black Fever," this is a kind of deadly hepatitis that kills in less than a week, and is caused by the joint action of the B and Delta virus. The total number of victims is unknown, but in one small city of 2,000 inhabitants, there have been 18 deaths so far this year, and 30 last year. Doctors say they don't know the epidemiology of the Delta virus. A professor at the science faculty in Manaus, Jose Carlos Fonseca, has stated that the virus needs another virus, that of hepatitis B to multiply. Entire families usually die from this virus. The possibility has been mentioned that the virus is transmitted by mosquitos. Tests show 38% of Amazonia families studied were carrying the Delta virus, while that 10% of the population were carrying the B virus.

The situation in the state of Rondonia is such a disaster that the Brazilian government has withdrawn all their propaganda campaigns which encouraged Brazilians to move there. They used to advertize Rondonia as "The biggest land reform ever tried," and are now placing ads saying "don't go to Rondonia, there is no land left."

Indonesian rain forests are being destroyed almost as rapidly as those in Brazil. Although no satellite study has been done of the Asian rain forest, it is estimated that logging companies cut more than 800,000 hectares a year,while shifting cultivators following behind cut about 200,000 hectares of mostly previously logged and damaged or secondary forest. As in Brazil, transnationals, in this case Georgia Pacific and Weyerhaeuser, are responsible for most of the deforestation, while the World Bank builds the roads that gives the transnationals access to the rainforest, and, as in Brazil, it is "resettling" millions of families to the areas cleared by the logging companies.

The rain forest and global climate

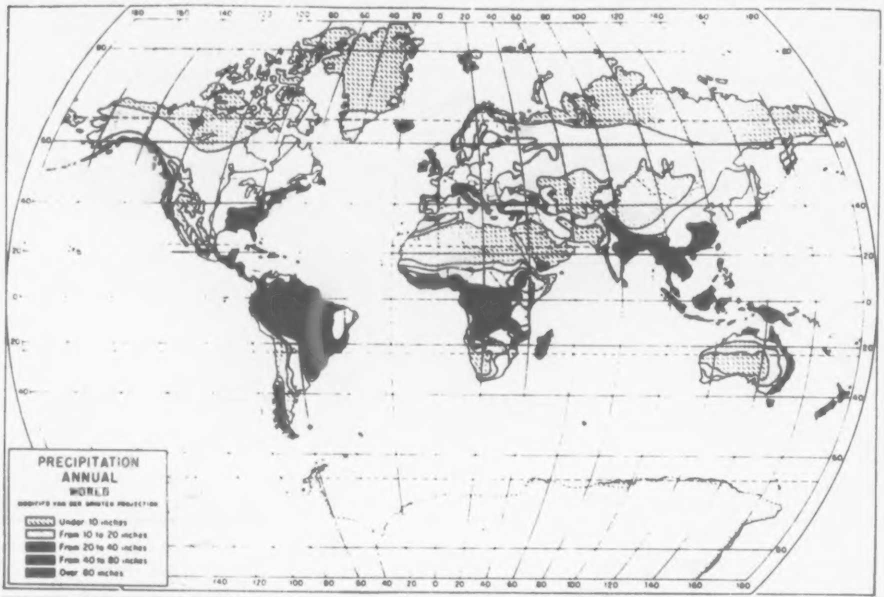
The three most important tropical ecosystems in the world, which provide the vast majority of water vapor transpired from landmasses into the atmosphere, are located in the Amazon, the delta of the Zaire (Congo) River, and Indonesia. The greatest amount of global precipitation falls on these tropical rain forests as can be seen in Map 2. Disastrously, these are the areas, especially the Amazonas and Indonesia, where the greatest amount of deforestation is occurring.

Table 3 defines these areas and the forest types considered. Notice that Brazil posseses 30.68% of all the tropical forest in the world; Peru, Colombia, Bolivia, and Venezuela 16.5%; Indonesia by itself 9.78%; while the "deforestation belt'' of Asia--Burma, Indonesia, and Papua New Guinea--account for 15.36% of the world's tropical rain forest. In summary, the table shows that a mere 10 countries on the planet possess 75.62% of the world's rain forest.

The tropical rain forest functions as a solar engine. absorbing more sunshine than any other living land cover, moderating surface temperatures, and reducing heat reflection into the atmosphere. It uses this absorbed energy to combine atmospheric carbon dioxide gas to form all kinds of substances. It is the largest terrestrial net producer of oxygen. It is also the greatest source of water vapor into the atmosphere, which provides rain in other areas. As demonstrated in the now nearly extinct rain forest of Africa, deforestation creates a cycle of desertification, including a rise in temperatures as the albedo effect starts to take place, a result of cutting

MAP 2

Annual world precipitation


PRECIPITATION
ANNUAL
WORLD
MODIFIED VAN DER GRINTEN PROJECTION
Under 10 inches
From 10 to 20 inches
From 20 to 40 inches
From 40 to 80 inches
Over 80 inches
180
160
140
120
100
80
60
40
20
0
20
40
60
80
100
120
140
160
180

Source Clarence E Koeppe, *Weather and Climate*

Observe that the areas with the greatest amount of precipitation are the Amazon and Indonesia and surrounding areas. Water vapor is cleansed by the rain forest, including removal of CO_2, and recycled into the upper atmosphere together with a rich mixture of chemicals, which are then transported to other regions of the world. These rain forests are the critical "solar engines" that are being most thoroughly destroyed.

the green cover--and drought: Rain becomes scarcer when water vapor is no longer being returned into the atmosphere.

The complex workings of this biosphere and its relation to the atmosphere are largely unknown, but a recent joint study conducted by scientists from the United States and Brazil has provided a wealth of discoveries that are still being evaluated. The expedition, the Global Tropospheric Experiment/Amazon Boundary Layer Experiment (GTE/ABLE), was conducted above the Brazilian Amazon rain forest in July and August 1985 and in April and May 1987. It combined, for the first time, local measurements at ground stations, regional measurements aboard aircraft, and global measurements from the Space Shuttle and satellites, to study the influence on the troposphere of the world's largest rain forest and its influence on chemistry and meteorology of the Earth's atmosphere.

In a paper summarizing the results, mission scientist Robert C. Harris of NASA's Langley Research Center asserted that the data obtained supported hypotheses that:

1) Tropical rain forest environments are characterized by relatively intense sources of biogenically-produced gases and aerosols.

2) The world's largest rain forest, in the Amazon basin, is a region of frequent atmospheric instability with intense thunderstorm activity, resulting in a potential for rapid mixing of biogenic gases and aerosols at high altitudes, where they impact global tropospheric chemistry.

3) The tropical troposphere is a region of intense photochemical activity where sinks for certain biogenic trace gases (e.g., isoprene (C;i5H;i8)) produce sources of gaseous products (e.g., carbon monoxide, CO) that may be significant to global budget.

One of the most important discoveries was the role of Amazonian forest soils and vegetation as sources of nitrous oxide NO and C;i5H;i8 to the atmospheric mixed layer, and consequently, the potential for photochemical production of O;i3 (ozone) during the oxidation of C;i5H;i8.

The Amazon ecosystem removes ozone from the air in the forest and the air immediately overlying the forest. Concentrations of ozone are typically 40 parts per billion (ppb) in the upper atmosphere over the Amazon, decreasing to 20 ppb in the boundary layer; they go to undetectable levels at night in the forest. Thus, tropical forest ecosystems act as a filter, removing ozone from the air through reactions of hydrocarbon gases emitted by vegetation and by ozone uptake on soil and plant surfaces.

Large convective thunderstorms were observed to transport ozone from above 5 kilometers to the lower atmosphere where ozone removal occurs. Thus, the rain forest ecosystem removes ozone, a chemical poisonous to human and animal life in the forest, while it pumps ozone and basic chemicals in the formation of ozone, to the ozone layer. The destruction of the rain forest may therefore be one of the principal causes of the thinning of the ozone layer.

The ABLE-2 expedition also revealed that as air coming from the Atlantic Ocean flows over the Amazon to the Andes Mountains and exchanges of gases and aerosols (particles) occur, a series of chemical reactions are set off which eventually impact global air quality and the Earth's radiation budget.

Natural organic carbon makes up more than 80% of the aerosol mass. The chemical composition of aerosols changes as inflowing ocean air transects the Amazon Basin, and frequent rainstorms remove sea salt and mix forest aerosols up into the tropical atmosphere. Large convective thunderstorms typical of tropical regions can transport rain forest gases and aerosols to altitudes of greater than 6 kilometers, where they become integrated into the atmospheric circulation. These aerosols play important roles as cloud condensation nuclei, creating the conditions for rain to occur as water vapor is transported to other areas of the world.

Deforestation plays a critical role in destroying the climate of a region, through reduction of humidity and rates of plant evaporation and a change in the energy balance. In the Amazon forest, it has been calculated that 25.6% of precipitation is intercepted by the vegetation and returns to the atmosphere by direct evaporation, 45.5% is transpired by plants, and 25.9% is drained through the surface run-off. Therefore, about 75% of the precipitation returns to the atmosphere in the form of water vapor through the action of plants, indicating the importance of this type of vegetation cover for the components of the Earth's water budget. (The best overview of this subject is found in The Climatology and Hydrology of Amazonia, by Brazilian scientist Eneas Salati, from which these figures have been taken.)

Approximately 6,430 billion tons of water vapor are generated within the Amazon water basin as a whole through the direct action of plants in interception, evaporation, and transpiration. This is the same magnitude of water vapor as that coming from the ocean. There are several hypotheses as to what happens to this water vapor, but no direct studies of this have been done in the atmosphere. The best working hypothesis is that the water vapor generated by the Amazon moves toward the west, and is replaced by primary vapor generated in the Atlantic ocean. The Andean Mountains form a natural barrier 4,000 meters high and effectively prevent the exit of water vapor to the Pacific Ocean. This is the reason that the western side of the Andes on the Pacific Coast is so dry, while the eastern slope of the Andes has enormous precipitation rates.

The Andes Mountains funnel the water vapor both to the north and the south, depending on the latitude. Above the Equator, the rotation of the Earth would move the vapor northward over the Guyana Plateau and the Colombian and Venezuelan llanos (plains), the Amazon water vapor ending up in the Caribbean Sea, where most of the storms and hurricanes that hit the East and Gulf coasts of the United States are generated.

Below the Equator, the water vapor is driven south over the central plateau of Brazil and the lowlands of Bolivia, Paraguay, Argentina, Uruguay, and Brazil. The final destination of the Amazon water vapor is Antarctica, where it may also play a critical role in global climate.

Deforestation drastically changes this water and energy cycle. If there is less water available for evapotransportation, there will be a decrease in relative air-humidity, which will alter the energy balance. The incident solar energy, instead of being used for water evaporation, will be used for heating the air.

In addition, the change in vegetation cover involves a change in albedo--the power of light reflected on the surface under consideration. Changes in albedo also involve changes in the energy balance. Modifications of small areas surrounded by forest should not influence the energy and water balance or regional climate as a whole, but when thousands of hectares are involved, drastic local climatic changes occur, as can be witnessed in India and Africa.

Several studies have documented the role of deforestation in increasing the temperatures and sharply reducing precipitation in local areas of Africa, Asia, and the Amazon, but no large-scale studies have been done. Mr. Indra Kumar Sharma of India has written that, in India's Rajasthan region, the unreliability of the rains has increased as a direct result of deforestation, since the dry air currents rising off the hot ground dispel weak monsoonal fronts, whereas in contrast, the warm, moist air rising from vegetated areas promotes the buildup of local thunderstorms so that areas of dense vegetation receive 40% more rain than neighboring deforested areas.

It is also important to consider the effect of the variation in the quantity of vapor condensing in the higher parts of the atmosphere. During evaporation, solar energy is transformed into latent heat which is released in the highest layers of the atmosphere where the water vapor condenses to form clouds. This energy is partially responsible for the circulation of the upper atmosphere. Part of this vapor is transferred to the polar regions, and upon condensation, releases energy; this is one form of energy transfer from equatorial to polar regions.

Dr. Alberto Setzer has also warned about the effects on global climate of the massive burning of the rain forest. The huge cloud of smoke and gases produced by the burning is carried south by the regular wind currents. This may be one of the major contributing factors toward the thinning of the ozone layer in the Antarctic.

The pollution factor

The emission of pollution from the burning of the rain forest in Brazil is almost equal to the total air pollutant emissions in the United States in one year. According to calculations made by Dr. Setzer (see Table 4), 6.22 million metric tons of particulate matter were dumped into the atmosphere by the burning of the Amazon rain forest last year, while the total particulate matter released by all industrial, human, and non-human activity in the United States in 1986, according to the EPA, was 6.71 million metric tons. The total amount of carbon monoxide released into the atmosphere in the United States in 1986 was 60.96 million metric tons, while that released by the burning of Amazonia was 44.03 million metric tons. We will deal with this specific question in greater detail in a special section at the end of this report.

It would seem, as it did to all early explorers of the Amazon, that the soil must be very rich to grow such a lush forest. Yet, the truth is that tropical rain forests are found thriving on the poorest soils on Earth. The tropical rain forests have developed an extremely complex ecosystem that essentially captures all the nutrients necessary without recourse to the soil. A forest in temperate climates, such as the United States or Europe, is differentiated "horizontally.'' One walks in, and first, there are shrubs, then small trees, then tall trees; pine trees will dominate certain areas, while maple and oak trees will dominate other areas. In a rain forest, it is completely different. The differentiation is "vertical.'' There are five canopies of trees, each with its own specializations. The forest floor is very clean, with few leaves or rotting trunks, such as those found in temperate climate forests. Every nutrient is recycled immediately in a rain forest, before they are washed away by the rain. If a leaf falls, insects, bacteria, and fungi, which live in symbiotic relationship with the roots of the trees, will digest them immediately, and return the minerals and nutrients necessary for growth back to the canopy. In the canopy itself, there are "epiphytes,'' plants that capture all necessary nutrients and minerals from the surrounding air.

There are two major reasons why the areas where rain forests have been either cut or burnt down become desertified so rapidly. The first is the very poor quality of the soils under the forest canopy. The second is the volume of rain that falls--several feet a year. Once the forest cover is removed, severe erosion occurs, and whatever nutrients were above ground--such as the remains of burnt plants--or in the soil itself, are leached and washed out in a short period of time. Under primitive slash-and-burn methods, a tribe of Indians or peasants move into a spot, burn a small area, and cultivate it for two years, three at the most, before all the nutrients have been exhausted. Then, they have to move on to virgin forest. The rain forest can reclaim this small plot of land rather quickly. When the area becomes larger, however, the rain forest cannot recover.

Thus, tens of millions of hectares of Brazilian rain forest have now become desertified. Full-blown deserts, with moving sand dunes and sandstorms, have emerged in many areas of Brazil and other tropical countries where, barely 10 to 20 years ago, there was lush tropical rain forest.

Tropical forests are also being destroyed by the systematic harvesting of logs to make charcoal. Even in the case where trees are replanted to replace those cut down, the same problem exists as with slash-and-burn agriculture. The original nutrients are taken away with the trees. Thus, the seedlings seldom survive. Vast areas of tropical rain forest have been cut down to make charcoal, especially in Africa where fuelwood and charcoal represent between 60% and 90% of all the energy used in most countries.

Again, Brazil represents the most criminal case, where 5.34 million metric tons of charcoal were produced in 1986, more than one-quarter of the total production of charcoal in the world. Under orders from the IMF/World Bank, Brazil is limited in its importation of coal for steelmaking, in order to preserve its foreign reserves to pay its foreign debt. Not possessing significant coal reserves, Brazil utilizes the charcoal to turn iron ore into pig iron, despite the fact that importing much higher quality anthracite coal from the United States would be cheaper and would employ tens of thousands of miners in some of the most depressed areas of the United States.

In sum, millions of hectares of lush rain forest have been cut down and turned into wastelands, to please the wishes of international bankers.

THE HOAX BEHIND THE GREENHOUSE THEORY ADVOCATES

The leading advocates of the so-called "Greenhouse Theory" claim that industrial emissions are responsible for the greatest amount of Carbon Dioxide being released into the atmosphere every year. What they carefully avoid, however, is dislosing the large amounts of Carbon Dioxide relased by "renewable resources", the burning of biomass. Residential woodburning in the United States dumps seven times more carbon monoxide into the atmosphere than all other emissions from fuel combustion sources combined. According to the Environmental Protection Agency's "National Air Pollutant Estimates'" the total amount of carbon monoxide dumped into the atmosphere from fuel combustion sources in 1986 was 7,187 gigagrams/year. Of this, residential wood burning accounted for 6,280 gigagrams/year, that is 87% of the total. The same EPA figures reveal that the total amount of carbon monoxide produced by coal, fuel oil, and natural gas burned in electric utilities in 1986 was 280 gigagrams/year. In other words, residential wood burning dumped 22.5 times more carbon monoxide into the atmosphere in the United States than all electric utilities combined.

"Environmentalist" policies, specially those implemented during the administration of President Jimmy Carter, are directly responsible for a doubling in the amount of carbon monoxide dumped in the atmosphere from fuel combustion sources. In 1975, the year before Jimmy Carter became president, the total amount of carbon monoxide emitted from these sources, as estimated by the EPA, was 4,220 gigagrams/year. Upon Carter's arrival in the White House, the official policy became to shut down the nuclear industry and to forster "renewable" and "clean" energy sources, such as solar energy and biomass burning. Massive credits and incentives were created to foster the use The result, by 1982, the year after Carter had left office, the total emissions from fuel combustion sources reached 8,015 gigagrams/year of carbon monoxide, nearly double the 1975 figures! The greates increase in carbon monoxide poisoning of the atmosphere came due to residential woodburning, which more than doubled, from 3,170 gigagrams/year of carbon monoxide in 1975, to 7,060 gigagrams/year in 1982.

The state of Colorado recently banned the use of woodstoves and fireplaces due to the enourmous amount of pollution which they produce. According to EPA figures, in 1986 the soot produced by burning firewood in residences accounted for more particulate emissions into the atmosphere throughout the United States than all electric utilities, railroads, aircraft and vessels put together, and as much as all highway vehicles. As a result of Jimmy Carter's "environmentalist" policies, the amount of particulate emissions from residential woodburing more than doubled during the Carter administration, from 0.5 teragrams/year in 1975, to 1.1 teragrams/year in 1982.

Despite the massive evidence that woodburning, either from residential and comercial use in the advanced sector, or the wanton burning of rainforest and vegetation in underdeveloped nations, dumps enourmous amounts of carbon pullutants into the atmosphere, the advocates of the "greenhouse theory" have chosen ignore this evidence, and target industry as the culprit instead. If they are serious about their catasthropic warnings from the release of carbon pollutants into the atmosphere, then they should campaign for nuclear and fusion energy, and the rapid industrialization of the underdeveloped nations.

SIERRA
CLUB

330 Pennsylvania Avenue, S.E., Washington, D.C. 20003 (202) 547-1141

September 28, 1988

The Honorable Timothy E. Wirth
United States Senate
Washington, D.C. 20510

Dear Senator Wirth:

It has come to our attention that testimony presented at your September 20, 1988 hearing on global warming and tropical deforestation may have given rise to a misunderstanding of the Sierra Club's position on your legislation, S.2667, and, more specifically, on the provisions in your bill which would authorize the development of an "advanced" nuclear reactor.

To clarify the record, we hereby request your indulgence to include in the written record of the hearing the enclosed letter dated July 27, 1988, by which we first communicated our position on these matters to you. This letter continues to represent our thinking on this issue. We would be glad to discuss these matters in detail at your convenience, and to testify on them at the appropriate opportunity.

Sincerely,

Douglas Scott

Douglas Scott
Conservation Director

Enclosure

"When we try to pick out anything by itself, we find it hitched to everything else in the universe." *John Muir*

SIERRA
CLUB

330 Pennsylvania Avenue, S.E., Washington, D.C. 20003 (202) 547-1141

July 27, 1988

The Honorable Tim Wirth
U.S. Senate
Washington, DC 20510

C-O-P-Y

Dear Senator Wirth:

I appreciated the opportunity to meet with you yesterday to discuss your draft global warming bill. As always, it is heartening to work with a Senator as committed to solving our environmental problems and as well-informed as you are. Your bill has many excellent provisions which will lay the groundwork for an effective fight to stop global warming.

I want to be sure that you understand before the bill is introduced that the Sierra Club will oppose the funding authorization in the bill for research and development of a "safe" nuclear power plant. We have doubts that development of such a plant is possible, and strongly believe that commitment now to such an expensive program is a misplaced priority in the much-needed fight to stop global warming. It is inconsistent with other provisions of the bill aimed at least cost energy planning.

I would strongly urge you to reconsider the proposal advanced by Dick Ayres and others yesterday to lump all the new research and development authorization into one pool with strict criteria for cost-effectiveness and efficacy in reducing greenhouse gases. While such action may reduce the political support for the proposal at the outset, it will have the significant advantage of reducing opposition to part or all of your bill.

If you still feel that you must go forward with the ear-marked authorizations, I would then urge you to consider handling this in the same way that you have handled the CAFE standards legislation, by introducing it as a separate piece of legislation. You and other Senators who support it could still describe it as part of your package for dealing with the global warming problem. The Sierra Club would then fight whole-heartedly on behalf of the other excellent elements of your bill. Those in the nuclear industry can compete for the funding which they desire, just as we will fight to adopt the CAFE legislation.

The Sierra Club looks forward to working with you on the global warming issue. If I can help you in any way, please let me know.

Sincerely yours,

David Gardiner

David Gardiner
Legislative Director

"When we try to pick out anything by itself, we find it hitched to everything else in the universe." *John Muir*
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COMMENTS OF

WENDY H. BAER
EXECUTIVE VICE PRESIDENT
INTERNATIONAL HARDWOOD PRODUCTS ASSOCIATION

SUBMITTED TO
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

Summary of Comments

The International Hardwood Products Association (IHPA) is the sole organized group in the United States which represents importers of tropical wood products as well as overseas producers of tropical wood products. In addition, this Association enjoys close working relationships with overseas organizations which represent the producers. Our comments are submitted with regard to S. 2667, introduced by Senator Timothy Wirth on July 28, 1988. More specifically, our comments relate to that portion of the Bill which addresses strategies to promote reforestation, afforestation and conservation of existing forest resources in the U.S. and worldwide.

The industry represented by IHPA is aware of the urgent need for initiation of major efforts to combat the threat of global warming. The largest contributor to global warming is placed upon high levels of CO2 emissions which result from widespread burning of fossil fuels. The reduction of CO2 emissions through drastic reduction in the use of fossil fuels must be a priority. As proposed in the Bill, major emphasis must also be given to energy research and conservation, atmospheric research , research into new forms of nuclear power production and international population control.

IHPA is also aware that expanded reforestation efforts on a worldwide basis can effectively contribute to curbing high levels of CO2 in the atmosphere. IHPA, in our position as an association which has as its members both overseas producers and U.S. importers, would be pleased to cooperate in working with the Congress, U.S. Government authorities, and with the supplying countries in the development of realistic and reasonable standards for reforestation, afforestation and conservation of tropical forest resources.

Our attached comments are submitted for your consideration.

IHPA

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COMMENTS OF

WENDY H. BAER
EXECUTIVE VICE PRESIDENT
INTERNATIONAL HARDWOOD PRODUCTS ASSOCIATION

SUBMITTED TO
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

I thank you for the opportunity to submit comments to the Committee on Energy and Natural Resources of the U.S. Senate. My comments are with respect to S. 2667, proposed by Senator Timothy E. Wirth. The Bill seeks to establish a national energy policy to reduce global warming and for other purposes.

I serve as Executive Vice President of the International Hardwood Products Association. Today, on behalf of the industry represented by the International Hardwood Products Association (IHPA), I wish to comment on that portion of the Bill which addresses proposed strategies to promote reforestation, afforestation and conservation of existing forest resources in the U.S. and worldwide. Over my twelve years with the Association, I have gained a feel for the members businesses and concerns. Therefore, while the entire membership of IHPA has not been consulted on my remarks which follow, I am confident that they will support them. A general members' and Board of Directors meeting will take place in a couple of weeks, and S. 2667 will be a major topic for our discussion.

The International Hardwood Products Association was established 33 years ago to represent the interests of the imported hardwood plywood industry. As imports in wood and wood products expanded, so the Association expanded its services to address issues before the entire tropical forest products industry. Membership not only includes companies which import approximately 75% of the entire U.S. wood products consumption annually. Membership also includes exporters of forest products, allied services such as port authorities, steamship companies, manufacturers, and the companies in many producing countries which supply these products to the United States. This Association also works closely and in cooperation with many of the major organizations in tropical countries which produce wood products imported into the United States. On invitation of U.S. Government representatives, IHPA has also named industry representatives which have served as official advisors to the U.S. delegation to the International Tropical Timber Organization in two recent ITTO Council meetings and will advise at the November ITTO meeting in Yokohama.

The International Hardwood Products Association shares widespread concern over the implications of global warming to our future generations. Members of the IHPA and this industry, I am sure, would express support of efforts to establish responsible regulations and to enact appropriate measures, both nationally and worldwide, which would contribute to slowing the rate of change in our atmosphere.

In reviewing the opinions of many foresters, scientists and authorities who have studied to a great extent the changing atmosphere, we also support the belief that successful world reforestation efforts would contribute, though be it a small contribution, to solving the problem of high CO2 levels in the atmosphere. It is a fact, however, that the major contributor to high current levels of CO2 is widespread use of fossil fuels, and great amounts of research and cooperative action between governments and the private sector will be required to stem the use of fossil fuels. As Gregg Marland (Environmental Sciences Division, Oak Ridge National Laboratory) has suggested in comments related to this issue, to stimulate the growth of forests is entirely appropriate, but can be viewed only as "an interim measure with limited capacity and would be useful primarily to buy time while our energy system is weaned from fossil fuels."

Tropical reforestation, conservation and plantation research and efforts have been initiated and are currently being developed in many producing countries - including but not limited to Brazil, Malaysia, Latin America, Costa Rica, China, S. Korea, Indonesia. Results of the programs are mixed, but the existence of such programs indicate an awareness of a problem. Attempts to slow down rates of deforestation are there.

Our concern over the effects of global warming is not tempered by the businesses our membership represents. It does, however, bring to the fore a concern as well that reasonable and well thought out approaches be taken to encourage producing countries to establish and enforce more effective reforestation and sustained yield programs for future generations. Negative economic impact on the producing countries of severe worldwide prohibition on imports of their tropical wood products could in many ways offset the very purpose of such a proposal. The incentives (put forth in S. 2667) of reduction of foreign debt and for producing countries to meet realistic criteria of reforestation in order for imports of their timber products into the U.S. (and other consuming countries) to be allowed are both steps in a direction which may need to be taken.

Dr. Freezailah, Executive Director of the International Tropical Timber Organization, has stated, "There can be no conservation without utilization." We agree that the two must go hand in hand, with sensible management programs to guide them. We also agree with Dr. Freezailah when he states, "Even if there were a total ban on the export of tropical timber, the tropical forests would disappear." As you are aware, the causative factors for deforestation are many. The main contributing factor to deforestation is clearing for shifting cultivation and farming. This has been linked to road construction for logging and other purposes.

May I reitterate here, IHPA works closely with many of the producing country wood product associations, and they in turn work closely with their respective government authorities. Annually, in the Fall, IHPA conducts a visit to Southeast Asia to discuss with each association current supply and market situations, and efforts to conserve current forest resources and tropical reforestation.

The introduction of S. 2667 is timely, in that a U.S. delegation will visit next month with these very organizations in Taiwan, the Philippines, Thailand, Malaysia and Indonesia. Twenty three U.S. wood industry members will formally meet in Jakarta with delegates from the Philippines, Thailand, Malaysia and Indonesia. Eighty four industry delegates from Indonesia alone will be in attendance to discuss with the U.S. delegation the future of their supply, their markets, their reforestation plans. The Indonesian Minister of Trade, and the Minister of Forestry will participate. Implications to the timber producing and buying industries of the proposed "National Energy Policy Act of 1988" will be a major topic of discussion. An IHPA industry representative will serve as an advisor to the U.S. delegation to the ITTO in Yokohama in November.

Trade in timber products is an important industry in the U.S. Proper management of the tropical forests can only serve to prolong the life of this industry. Members and businesses in the industry, and this Association, have addressed the need for reforestation efforts worldwide within the framework of concern for future supply. This framework now expands to include the contributory role which realistic reforestation programs in the producing countries can play in partially stemming the alarming buildup of CO2 in the earth's atmosphere.

As is proposed in S. 2667, should this Bill come to fruition, we encourage very careful inventory of resources in the producing countries, and very careful and realistic evaluation of the potential in each tropical country for reforestation, afforestation and conservation of the existing forest resources. The criteria which may be established for each country to meet must be reasonable and well thought out - and must be realistic in terms of ability to achieve the established criteria. This is no simple project.

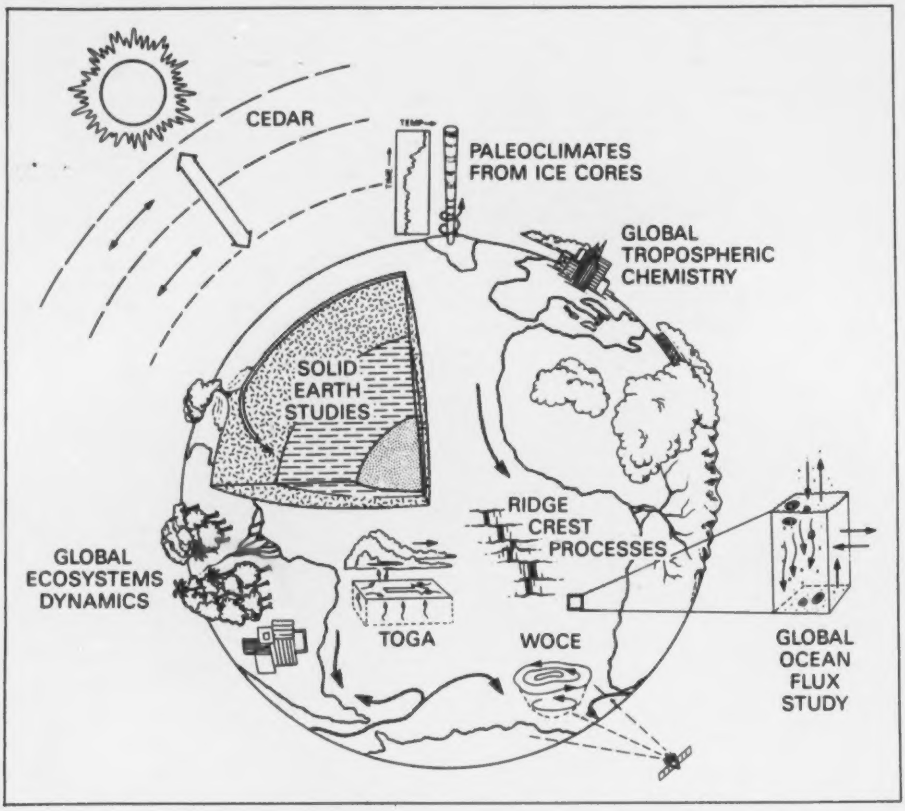
While the improvement of our world's forests alone will not solve the problem of global warming, it is one of many important elements in the program which should be addressed. I will recommend that the International Hardwood Products Association's Board of Directors initiate the development of efforts in our industry to support accomplishment of reasonable goals for reforestation in our producing countries.

Thank you for accepting comments from the International Hardwood Products Association on this most important issue, and we look forward to addressing any questions the committee may have.

W. Baer
Wendy H. Baer
Executive Vice President
International Hardwood Products Association
October 4, 1988

NATIONAL SCIENCE FOUNDATION **PROGRAM DESCRIPTION**

FY 1988 GLOBAL GEOSCIENCES PROGRAM


CEDAR
TEMP
TIME
PALEOCLIMATES FROM ICE CORES
GLOBAL TROPOSPHERIC CHEMISTRY
SOLID EARTH STUDIES
RIDGE CREST PROCESSES
GLOBAL ECOSYSTEMS DYNAMICS
TOGA
WOCE
GLOBAL OCEAN FLUX STUDY

DIRECTORATE FOR GEOSCIENCES
DIRECTORATE FOR BIOLOGICAL, BEHAVIORAL, AND SOCIAL SCIENCES **JULY 1987**

NATIONAL SCIENCE FOUNDATION

FY 1988 GLOBAL GEOSCIENCES PROGRAM

STATEMENT OF PURPOSE

This booklet describes the National Science Foundation Global Geosciences Program as presented to the 100th Congress for fiscal year 1988. It presents an overview and status of the Global Geosciences program, and provides descriptions of the component program elements.

The chart of the Global Geosciences Program illustrates how the program elements study different aspects of the earth system, lists the principal research objectives for each program of study, and shows how the research components are interrelated. The chart shows the current participation by other U.S. federal agencies.

A bibliography lists key publications and workshops related to Global Geosciences.

Global Geosciences is a Foundation-wide activity, jointly supported by the Directorate for Geosciences and the Directorate for Biological, Behavioral and Social Sciences.

William J Merrell Jr	David T. Kingsbury
Dr. William J. Merrell, Jr. Assistant Director Geosciences	Dr. David T. Kingsbury Assistant Director Biological, Behavioral and Social Sciences

June 1987

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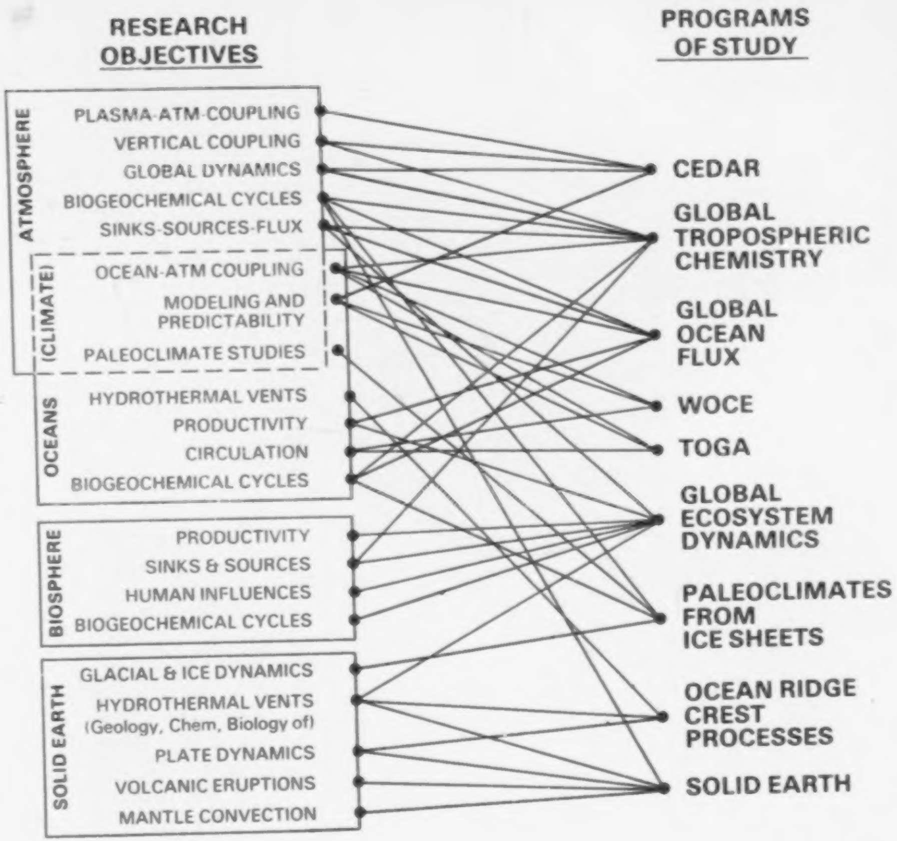
NSF FY 1988 GLOBAL GEOSCIENCES


RESEARCH OBJECTIVES
ATMOSPHERE
PLASMA-ATM-COUPLING
VERTICAL COUPLING
GLOBAL DYNAMICS
BIOGEOCHEMICAL CYCLES
SINKS-SOURCES-FLUX
(CLIMATE)
OCEAN-ATM COUPLING
MODELING AND PREDICTABILITY
PALEOCLIMATE STUDIES
OCEANS
HYDROTHERMAL VENTS
PRODUCTIVITY
CIRCULATION
BIOGEOCHEMICAL CYCLES
BIOSPHERE
PRODUCTIVITY
SINKS & SOURCES
HUMAN INFLUENCES
BIOGEOCHEMICAL CYCLES
SOLID EARTH
GLACIAL & ICE DYNAMICS
HYDROTHERMAL VENTS (Geology, Chem, Biology of)
PLATE DYNAMICS
VOLCANIC ERUPTIONS
MANTLE CONVECTION
PROGRAMS OF STUDY
CEDAR
GLOBAL TROPOSPHERIC CHEMISTRY
GLOBAL OCEAN FLUX
WOCE
TOGA
GLOBAL ECOSYSTEM DYNAMICS
PALEOCLIMATES FROM ICE SHEETS
OCEAN RIDGE CREST PROCESSES
SOLID EARTH

INTERAGENCY PARTICIPATION

	NASA	NOAA	USGS	DoD	ONR
CEDAR	X	X		X	
GLOBAL TROPOSPHERIC CHEMISTRY	X	X			
GLOBAL OCEAN FLUX	X	X			
WOCE	X	X			X
TOGA	X	X			
GLOBAL ECOSYSTEM DYNAMICS	X		X		
PALEOCLIMATES FROM ICE SHEETS			X		
OCEAN RIDGE CREST PROCESSES		X	X		
SOLID EARTH	X		X	X	

GEO: 3-6-87

FY 1988 NATIONAL SCIENCE FOUNDATION

GLOBAL GEOSCIENCES PROGRAM

INTRODUCTION

In FY 1987 the National Science Foundation began a new program called "Global Geosciences" to support studies of the earth as a system of interrelated physical, chemical, and biological processes which regulate the habitability of our planet. The goal of Global Geosciences is to understand the earth system, how it functions, and to describe and predict major cause and effect relationships among earth processes. Beyond intrinsic scientific interest, this program is important because the environmental system affects the quality of life on earth.

THE PROGRAM

NSF proposes expanding Global Geosciences in its FY 1988 Budget request to Congress. The enhanced program includes the following:

Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR)
Global Tropospheric Chemistry Program (GTCP)
Global Ocean Flux Study (GOFS)
World Ocean Circulation Experiment (WOCE)
Tropical Ocean/Global Atmosphere (TOGA)
Global Ecosystem Dynamics
Paleoclimate Studies from Ice Sheets
Ocean Ridge Crest Processes
Solid Earth Studies

A summary for each program element is provided.

SCIENTIFIC RATIONALE FOR DOING GLOBAL EARTH STUDIES NOW

Opportunity and need have galvanized scientific interest and influenced public opinion on the importance of understanding the earth as a system. The rationale for this focus on global interactive sciences is threefold:

1. Long-term observations of our environment reveal natural and anthropogenic changes in the delicate earth system, some of which may be irreversible and currently have an unpredictable effect. It is imperative to understand the processes contributing to such environmental changes as increasing carbon dioxide and other greenhouse gases, stratospheric ozone depletion, deforestation, and desertification.

2. At the same time, technological advances enable us to measure and observe the earth better than ever before. Satellites can now monitor certain critical biological, chemical, geological and physical parameters over large spatial scales. In-situ measurements using high-speed, high-precision instruments provide a necessary complement to validate and calibrate the cruder but larger scale satellite data.

   Combining remote sensing capabilities with field observations offers the potential for the acquisition of global data sets, and thus make possible for the first time simultaneous pictures of global processes such as ocean and atmospheric circulation, and distribution and densities of ocean and terrestrial biota.

3. State-of-the-art scientific computing allows for computer communications, data management and processing, networking, and sophisticated modeling of earth systems.

INTERAGENCY AND INTERNATIONAL COORDINATION

NSF is coordinating its Global Geosciences research programs with other agencies (NASA, NOAA, USGS, DOE, and the Navy), as well as with other countries. Planning of several Global Geosciences sub-programs has proceeded at the international level by Scientific Steering Groups sponsored by the International Council of Scientific Unions (ICSU) through such committees as Scientific Committee on Oceanographic Research (SCOR), and Scientific Committee on Problems in the Environment (SCOPE); through the World Meteorological Organization (WMO), UNESCO'S Intergovernmental Oceanographic Commission (IOC), and others. For example, WOCE and TOGA are major elements of the World Climate Research Program of the WMO, and are also supported by the IOC, and SCOR (through the Committee on Climate Changes in the Ocean).

NSF is committed to long-term funding of the implementation of the constituent programs of Global Geosciences. The Global Geosciences Program will continue for at least a decade, and will rely on close coordination and cooperation with science agencies and institutions in the U.S. and abroad.

Specific details on interagency and international coordination for each of the Global Geosciences sub-programs are included in the program summaries.

ICSU SUPPORT FOR THE INTERNATIONAL GEOSPHERE/BIOSPHERE PROGRAM

Concurrent with NSF's formation of the Global Geosciences Program the International Council of Scientific Unions (ICSU) developed the international focus on the habitability of our earth environment. In September 1986 the General Assembly of ICSU endorsed a program of study called the "International Geosphere-Biosphere Programme (IGBP): A Study of Global Change." At the ICSU assembly the recommendations for the IGBP were strongly supported by scientists from east and west, from developed and developing countries, and from all scientific disciplines. The objectives of the IGBP are:

> "to describe and understand the interactive physical, chemical, and biological processes that regulate the total Earth system, the unique environment it provides for life, the changes that are occurring in that system, and the manner by which these changes are influenced by human interactions."

The Swedish government is providing the secretariat for the ICSU special committee, chaired by Dr. James McCarthy of Harvard. The National Research Council's Committee on Global Change will serve as the U.S. National Committee for the IGBP. This committee proposes to provide guidance to federal agencies concerning the planning and implementation of U.S. scientific activities in support of the IGBP, advise U.S. participants in international planning activities, and provide a focus for development of new initiatives for the IGBP. Financial support for the Committee on Global Change will come from the federal agencies involved and be coordinated by the National Science Foundation.

COUPLING, ENERGETICS AND DYNAMICS OF ATMOSPHERIC REGIONS

CEDAR

Purpose

The objective of CEDAR (Coupling, Energetics and Dynamics of Atmospheric Regions) is to understand the coupling between atmospheric regions both vertically (between the Mesosphere/Thermosphere/Ionosphere/Exosphere/Magnetosphere) and globally (from high to low latitude and dayside to nightside). It is clear that coupling processes have important effects on the structure and variability of the regions concerned. Modelling the coupling processes on a global scale is now possible with the availability of large computers. Observational data to establish the nature of the coupling, and to test and refine the global models, requires campaigns of coordinated measurements with networks of state-of-the-art optical and radio instruments. The CEDAR program outlines plans and priorities for coordinated campaigns over the next five years, including the development of instrumentation with the necessary sensitivity and resolution.

Evidence of Need

CEDAR will fulfill the need to study the global middle and upper atmosphere as a coupled entity. In recent years it has been recognized that the middle and upper atmosphere regions cannot be studied as local entities but must instead be studied together. For example the composition and dynamics of the low latitude thermosphere are affected in a matter of hours by winds and waves from high latitude energy inputs during magnetic storms. Similarly, the stratosphere is the source of tides and planetary waves and gravity waves that transport momentum to thermospheric levels, and enhance eddy mixing there. Constituents such as nitric oxide (NO) produced at high latitudes during magnetic storms are transported to lower latitudes and lower altitudes and affect ozone concentrations and the thermal structure. Studies of thermospheric dynamics require a knowledge of the highly variable ionospheric structure to include properly the effects of ion-neutral drag. The ionospheric structure is in turn dependent on the neutral dynamics.

The CEDAR program evolved in a series of workshops and interacting studies by a theory/modelling subcommittee and six instrument specialty subcommittees. The report **"CEDAR, Coupling, Energetics and Dynamics of Atmospheric Regions" Volume 1, Overview**, recommended coordinated multi-instrument studies of vertical and horizontal atmospheric coupling. These studies require developing new state-of-the-art optical facilities (spectrographs, interferometers, monochromatic imagers, and lidars), and upgraded radar facilities (incoherent scatter radar, and mesospheric radars).

Description and NSF role

A list of twelve current CEDAR coordinated campaigns was listed in a recent report in EOS (68:75, 1987). These include projects for which working groups are being formed as well as more mature projects in which campaigns are already being conducted and results analyzed in workshops. The scientific objectives will broaden as new instrumentation becomes available. There are three phases of the CEDAR program. Phase I involves coordination of observations using existing instruments. Phase II involves upgrading instruments and establishing additional observing stations to fill out the global grid. Phase III realizes the full potential of the CEDAR program, with the establishment of "Class 1" facilities deployed at 6 to 8 strategically located sites, with full scale integration of several state of the art "Class 1" instruments at each observatory.

The CEDAR program is guided by a Steering Committee. The committee meets several times per year and runs an annual open planning workshop at NCAR. As more facilities are developed, NSF will play an increasing role in their management and access by visiting scientists. Many optical instruments will be portable, and will be taken to specific locations for campaigns. NSF together with the CEDAR steering committee will oversee these campaigns.

Interagency Cooperation

CEDAR is currently an NSF program, but also has been designated a component of the multi-agency National Solar Terrestrial Program. Future plans call for participation by NASA, NOAA, and DoD.

International Participation

CEDAR is a component of the international ICSU Scientific Committee for Solar Terrestrial Physics/World Ionosphere-Thermosphere Study.

GLOBAL TROPOSPHERIC CHEMISTRY PROGRAM

Purpose

The Global Tropospheric Chemistry Program (GTCP) has the following objectives:

to understand the basic chemical cycles in the troposphere through field investigations, theory aided by numerical modeling, and laboratory studies;

to predict tropospheric responses and consequences of natural and human-induced perturbations to these atmospheric chemical cycles; and

to provide the fundamental information required for effective future understanding of the atmospheric component of the global life support system.

Evidence of Need

The importance of atmospheric chemical and physical processes on planetary life support systems highlighted recently by research discoveries and by several problems such as smog, acid rain, and ozone depletion. In addition, perturbations to the chemical composition of the atmosphere have important implications for global climate. The identification of such problems and questions can be expected to increase in frequency and variety during the next few decades. Attempts to answer basic questions about these potentially important societal issues have been frustrated by the lack of knowledge of tropospheric chemistry.

Description and NSF Role

The Global Tropospheric Chemistry Program is a coordinated research effort to understand the fundamental processes that control the composition of the troposphere. Emphasis will be placed on:

understanding the biological sources of atmospheric gases and particles;

understanding the chemical processes responsible for creating and destroying chemical compounds in the atmosphere;

understanding the physical processes responsible for distributing various chemical compounds and removing them from the troposphere;

developing improved models of chemical processes in the atmosphere to permit more realistic predictive capabilities;

developing advanced methods for measuring trace species concentrations and their cycles through the atmosphere.

Facilities and trained personnel are now available to begin parts of this research effort. NSF will take an active role in initiating this program. There is interest in both developed and developing countries. Significant international expertise and facilities exist primarily in Western Europe but also in Japan, the USSR, Brazil, Canada and Australia.

Interagency Cooperation

GTCP is proposed as a national initiative led by NSF, with involvement by NASA, and NOAA. These agencies have been involved in planning the GTCP, are ready to provide the necessary programmatic support, and will have the prime responsibility for nurturing the scientific program and ensuring a long-term support base. DOE and EPA are also expected to make significant contributions to this global research effort. The Subcommittee on Atmospheric Research of the Committee on Atmospheres and Oceans of the Federal Coordinating Council for Science, Engineering and Technology has formed a working group for interagency planning, implementation and coordination of the National Global Tropospheric Chemistry Program.

International Participation

The U.S. Global Tropospheric Chemistry Program is envisaged initially as a national effort. The U.S. program coordinators will communicate with their relevant program counterparts in other countries over the first 5-6 years.

Large national programs in atmospheric chemistry are underway in several European countries and in the Soviet Union, Australia and Japan. In Europe, coordination of the national programs is occurring through the European Science Foundation, through individual scientists who have formed an organization called EUROPICA, and through the efforts of several European governments who are proposing a joint program called EUROTRAC.

Three organizations that are part of the International Council of Scientific Unions are seen as appropriate forums for formal coordination of the tropospheric chemistry programs in the U.S. and other countries. The Commission on Atmospheric Chemistry and Global Pollution would provide a vehicle for organization of international meetings and joint endeavors, while the ICSU International Geosphere-Biosphere Programme (IGBP) would provide a vehicle for interfacing the tropospheric chemistry activity with the other relevant earth science disciplines on an international scale. The ICSU Scientific Committee on Problems of the Environment also is involved with planning for coordination of GTCP activities with its other programs.

GLOBAL OCEAN FLUX STUDY

GOFS

Purpose

The objective of the Global Ocean Flux Study (GOFS) is to identify and quantify the processes controlling biogeochemical cycling in the ocean, and their interactions with the global atmosphere. The goal is to understand the processes governing the production and fate of biogenic materials in the sea and to predict their influences on, and responses to, global scale perturbations.

Evidence of Need

In the last few years, considerable and rapid development of methods for the measurement of rates and advances in our conceptual understanding of the processes regulating biogeochemical cycles has occurred. A reevaluation of near-surface primary production is in progress. Satellite observations provide for the first time the potential for large-scale synoptic data sets and enable the extrapolation of calibrated regional studies to larger spatial and temporal scales. The use of sediment traps has revolutionized concepts of particulate transport rates. Deployments of benthic chambers on the deep ocean bottom can now measure fluxes across this boundary. Exchanges at the coastal/ocean boundary are being studied intensely, as is the significance of lateral transport of material to the ocean's interior. It is recognized that, when these methods and concepts are taken together, they provide for the first time the ability to undertake coordinated studies on the flux of material in the sea that involve large spatial scales and long time periods, essential for obtaining a global understanding.

The need and outline of a GOFS Program are set forth in the NRC publication Global Ocean Flux Study, and subsequent working group reports distributed by the U.S. GOFS Planning Office. GOFS has been endorsed by the Ocean Studies Board of the National Academy of Sciences and the Advisory Committee of the Ocean Sciences Division of NSF.

Description and NSF Role

An essential foundation for marine biogeochemical flux studies is a knowledge of physical dynamics. Complementary programs such as the World Ocean Circulation Experiment, the Transient Tracers in the Ocean Program, and the completed Geochemical Sections Program will supply much of this necessary physical knowledge. The critical next step is to link these physical studies to our emerging understanding of biogeochemical fluxes and intensive in-situ observations of the fluxes of soluble and particulate phases in the oceans, and the transformations between them, coupled with the remote sensing of surface productivity.

Facilities and personnel are presently available to initiate this program. However, there is a critical need in the future for an ocean color sensor on a satellite because of the required global coverage. Also needed is the establishment of an Accelerator Mass Spectrometer Center dedicated to Ocean Sciences, due to the fact that cosmogenic nuclides in trace amounts such as carbon-14 may be used as tracers to follow and monitor the time scale of atmospheric, geological and oceanographic processes. AMS allows detection of such nuclides down to levels of 1 part in 1000, thus making viable the analyses of samples that are required to meet GOFS and WOCE objectives. The development of AMS technology requires dedication of accelerators, specialized technical and professional staff, and in its service to a diverse research community, could be considered as a regional, or national, center incorporating research and service functions. Due to sample requirements in the WOCE and GOFS Programs, a dedicated machine is needed.

Interagency Cooperation

NSF has assumed the lead in initiating GOFS but will continue to collaborate closely with NASA on their support of complementary satellite applications. NSF is supporting the vast majority of chemical and biological oceanographic research being conducted in the academic community which serves as the scientific foundation for GOFS.

International Participation

GOFS is international in scope, including participation and coordination with other Federal agencies and international organizations. NSF and the U.S. GOFS Planning Office at the Woods Hole Oceanographic Institution have played key roles in assisting scientists in the U.K. to develop a flux program. Coordination with other counterparts (e.g., France, FRG, Canada and Japan), is ongoing, as well as with a number of international scientific entities (e.g. the Scientific Committee of Oceanographic Research (SCOR), the International Council of Scientific Unions, and The Intergovernmental Oceanographic Commission.

Several countries (e.g. France, U.K. FRG) have announced ocean flux programs complementing the U.S. effort. A group of scientists sponsored by SCOR has recommended establishing an international program, a Joint-GOFS (JGOFS). Considerations are also being developed for close association of JGOFS with ICSU's International Geosphere/Biosphere Programme.

WORLD OCEAN CIRCULATION EXPERIMENT

WOCE

Purpose

The goal of WOCE is to determine the extent of climate predictability. Primary goals of WOCE are:

1. Understanding the general circulation of the global ocean enough to be able to model its present state and predict its evolution in relation to long-term changes in the atmosphere.
2. Providing the scientific background for designing an observing system for long-term measurement of the large-scale circulation of the ocean.

Evidence of Need

The ocean plays a central role in the variability of global climate. It is the principal reservoir of heat and appears to equal the atmosphere in the world-wide transport and redistribution of heat. Thus, to predict climate variations, it is necessary to describe and understand the ocean: its mean state, its variability, and its large-scale interactions with the atmosphere. Technological and scientific developments have made possible the planning for WOCE. These advances include: an increased understanding of ocean circulation and the sampling procedures needed to observe it; instrumentation for long time-series measurements; numerical ocean models and high-speed/high-capacity computers to use them; improved methods for measurements of chemical tracers; the means for measuring the ocean from vessels of opportunity; and the satellite- borne instrumentation that can obtain global observations of both atmospheric forcing and oceanic responses. Along with these developments has come an increased awareness that to address global societal problems related to the ocean will require a coordinated, global-scale program of ocean observation and modeling.

Description and NSF Role

NSF is leading WOCE planning, which is scheduled in three phases. The planning phase (1985-1987) is underway with funding for activities requiring long lead times in preparation for the main field work. The second pre-satellite operational phase (1987-1991) will include global in-situ measurements and selected regional programs in preparation for the fully operational phase (1991-1996), during which extensive in-situ and satellite observations will be coupled with numerical models and analysis. This five-year focused field study is expected to provide by 1995 the first comprehensive global survey of physical properties of the oceans. The resulting data sets will be used to establish the first global baseline for the long-term behavior of the ocean, and to test computer models of ocean circulation necessary to understand global climate dynamics and to predict decadal climate change. The results will also provide the physical context for new research in marine chemistry, biology and geology. Funding to the U.S. WOCE Planning Office, includes contributions from NASA and NOAA. Funding for long lead time activities is beginning in FY 1987.

The Tropical Ocean and Global Atmosphere (TOGA) experiment contributes substantially to WOCE. TOGA data sets will answer many questions asked by WOCE for the equatorial oceans. The interannual variability of TOGA data sets is a subset of the decadal time scales of WOCE data sets. With some improvements in communications, management and coordination, exciting results can be expected from these programs.

Interagency Cooperation

NSF leads the planning process, with contributions from NASA, NOAA, and ONR. NASA will provide the synoptic observing capability with TOPEX and NSCAT. NOAA will provide in-situ sea level data, operational meteorological data, and survey facilities. All three agencies will support research activities, with NASA and NOAA providing some in-house activities. ONR will contribute support for several process experiments.

International Participation

WOCE is a major element of the World Climate Research Program of the World Meteorological Organization and the International Council of Scientific Unions through their Joint Scientific Committee (JSC). WOCE is also supported by UNESCO's Intergovernmental Oceanographic Commission and ICSU's Scientific Committee on Oceanic Research through the Committee on Climate Changes in the Ocean (CCCO). Scientific guidance is provided by an international WOCE Scientific Steering Group sponsored jointly by JSC and CCCO. This group prepared a draft science plan for the experiment which has been endorsed by the U.S. Science Steering Committee for WOCE. Each participating country is expected to develop a national plan for WOCE which would contribute in the areas of their capability and interest to the overall experiment. The U.S. national plan is described in U.S. WOCE Planning Report Number 4.

THE TROPICAL OCEAN-GLOBAL ATMOSPHERE EXPERIMENT

TOGA

Purpose

The TOGA program has three scientific objectives:

1. To describe the tropical oceans and the global atmosphere as a time-dependent system in order to determine the extent to which this system is predictable on time scales of months to years, and to understand the mechanisms and processes underlying its predictability.
2. To determine the feasibility of modelling the coupled ocean-atmosphere system for the purpose of predicting its variations on time scales of months to years.
3. To provide the scientific background for designing an observing and data transmission system for operational prediction if this capability is demonstrated by coupled ocean-atmosphere models.

Evidence of Need

The TOGA program grew out of NAS studies of the El Nino/Southern Oscillation phenomena. El Ninos produce a strong anomalous warming of surface coastal waters off the west coast of South America, with significant and frequently devastating effects on local fisheries, and local and global climate patterns. Studies of the Pacific El Nino have resulted in a dramatic increase in knowledge of its character. Scientists have identified a sequence of interconnected ocean and atmospheric events which are reproducible in rudimentary models. The El Nino event in 1982-83 was the strongest and best- observed such event on record. This convinced the oceanography and meteorology communities that an organized approach with increased resources can lead to the ability to predict at least some aspects of these climate anomalies.

Description and NSF Role

TOGA, begun in January, 1985, includes a ten-year measurement program designed to characterize the interannual variability of the tropical ocean and global atmosphere, an air-sea flux study to characterize air-sea exchange on the synoptic scale, an effort to develop coupled ocean/atmosphere models which can predict at least some aspects of interannual variability, and a variety of process studies to investigate mechanisms of ocean and atmosphere variability and air-sea interaction. NSF supports process studies, diagnostic studies using long time-series of existing data, and modelling studies. Recent advances demonstrate the enormous potential of this program. For example, NOAA, NSF, and NASA have jointly sponsored sea level network and thermal observation programs based on experience during the 1982-83 event. Rudimentary coupled ocean-atmosphere models have used these data to allow unprecedented predictions of many aspects of the much milder event now occurring in 1986-87. A pre-TOGA NSF program in the central Pacific, (Tropic Heat) has changed our ideas of how the equatorial ocean responds to remote and local surface forcing. Other related programs led by NSF are being initiated in both the Atlantic and Indian Oceans. In 1987, NSF will also co-sponsor, with NOAA, a workshop to identify and address process studies for the Western Pacific.

TOGA will contribute substantially to WOCE (World Ocean Circulation Experiment, NSF lead). TOGA data sets will address many of the questions asked by WOCE for the equatorial oceans. The interannual variability of TOGA data sets is a subset of the decadal time scales of WOCE data sets.

Interagency Cooperation

NOAA, as lead agency, hosts the U.S. TOGA Project Office, which is partially staffed by NSF, and partially supported by NSF and NASA. Oversight is provided by the NAS/U.S. TOGA Advisory Panel, and by the National Climate Policy Board. As the TOGA program matures, it will exploit the capabilities of all three agencies: the monitoring and survey capability of NOAA; both operational and planned satellite remote sensors (NASA's TOPEX and SCATTEROMETER, the Navy GEOSAT, the French POSEIDON, the European ERS-1, and the Japanese MOS-1) for sea surface temperature, air-sea fluxes, sea surface topography, and synoptic surface winds; and new supercomputers resulting largely from recent NSF initiatives. These complementary contributions from several agencies have led to the participation, in both TOGA and WOCE, of computational scientists and mathematicians as well as oceanographers and meteorologists. Their participation will further expand the capability to rapidly assimilate and interpret the new massive data bases being generated.

International Participation

The TOGA Program is a major element of the World Climate Research program of the World Meteorological Organization (WMO) and ICSU. TOGA is also supported by UNESCO's Intergovernmental Oceanographic Commission and ICSU's Scientific Committee on Oceanic Research through the Committee on Climate Changes in the Ocean. Scientific guidance is provided by a TOGA Scientific Steering Group. Intergovernmental aspects of the program are administered by an International TOGA Project Office under the

Joint Planning Staff of the WCRP. TOGA combines efforts by several other countries, and has generated extensive enthusiasm for international cooperation.

GLOBAL ECOSYSTEM DYNAMICS

Purpose

The objective of research on global ecosystem dynamics is to understand the role of the terrestrial and freshwater parts of the biosphere in the context of an integrated earth system. This objective can be met through research on physical and biological processes governing atmospheric composition, climate, and element circulation in the biosphere that, in turn, govern the physical structure of the biosphere. This research must be performed from the biologically-rich tropical rain forests to the extremes of deserts and cold regions.

Evidence of Need

Numerous recent research findings demonstrate convincingly that the biosphere is not a passive component of the global system. Rather it is both a source of materials in global circulation and a receptor of these same materials. At issue is whether the biosphere is a long-term sink for materials such as sulfur, trace metals and other substances purely of anthropogenic origin which may have adverse effects on the structure of the biosphere or its sustained biological productivity. There is additional current concern about the direct role of biospheric structure and processes (e.g., forests and evapotranspiration) on climatological phenomena, as well as the role of biotic agents (e.g., condensation nuclei) in climatological processes. Because humans have the capacity to modify their habitat rapidly and extensively, the status of the biological and genetic diversity of the global biosphere is a primary concern. The questions thus raised, and the immediate need for sound scientific fact, are significant driving forces for understanding the earth as an integrated global system as well as the logical development of scientific inquiry and methodological advances. Ecological research is a complex multidisciplinary undertaking, often requiring long term study to understand natural cycles by which the biosphere operates.

Description and NSF Role

Research will address a broad array of objectives. Initial emphases, however, will be on biological diversity, structure and function of tropical ecosystems, and the development and application of remotely sensed data. Research projects will build upon NSF's network of Long Term Ecological Research (LTER) projects in major ecosystem types concerned with long term and large scale ecological questions. A comprehensive statement of program content would include:

1) role of climate change on ecosystems
2) processes controlling flux of biologically mediated atmospheric constituents
3) role of ecosystems as material sinks
4) biogeochemistry of terrestrial/freshwater environments
5) influence of terrestrial environments on ocean productivity
6) biological diversity of tropical forests and other habitats
7) influence of anthropogenic activities on ecosystem dynamics
8) scale dependent interactions of the biosphere

NSF is generally viewed as having a leadership position in ecosystem studies because of its already important role in support of basic research at colleges and universities. It is this base of scientists and facilities that will initially be called upon in this program. In numerical modeling and remote sensing applications, trained personnel, techniques and facilities will need to be developed. Because the study of ecosystems is a complex multidisciplinary undertaking, NSF already has extensive and well-tended working relationships with other agencies, including NASA and international collaborators, all of which will be essential to successful implementation.

Interagency Cooperation

LTERs attract cooperation and support from NASA and EPA, and are located on U.S. Forest Service lands. In the area of remote sensing, NASA provides the bulk of funding, in cooperation with NSF, for the First Intensive Field Experiment part of International Satellite Land Surface Climatology Project that will be conducted at an LTER site in Konza Prairie, Kansas.

International Participation

Ecosystem scientists are active in the ICSU International Geosphere-Biosphere Programme. They will be represented on both international and national committees. Various SCOPE activities (also ICSU) involve U.S. ecologists, as well as informal collaborations with groups focusing on special topics, like fertility of tropical soils. Many NSF projects are conducted in tropical countries, and as such require participation by host country scientists. These relationships at the level of the working are critical to international scientific cooperation.

PALEOCLIMATES FROM ICE SHEETS

Purpose

The objective of this initiative is to develop a global ice core research and analysis program. The goal is to reconstruct paleoclimatic sequences unavailable from any other source and to investigate and better understand the interactions among the physical processes constituting the global climate system. This first major new initiative will be the Greenland Ice Sheet Program (GISP II).

Evidence of Need

Evidence is mounting that the polar regions play a key role in causing global climatic fluctuations. In some cases, the polar regions are the driving force of such fluctuations. Alternatively, global warming may cause the disintegration of ice sheets, causing sea level to rise.

Predicting future climatic variations requires better quantification of the global scale response to perturbations within the climatic system. The predictive capability of global climate models will be significantly improved by the incorporation of realistic polar process data.

The paleoclimatic record preserved in ice sheets provides new and valuable insights into past climatic conditions and their variations. Ice sheets are unique in that they continuously preserve and record annual precipitation, atmospheric temperature and composition, the occurrence of explosive volcanic eruptions, and variations in solar activity. Deep ice cores will fill a vital gap in the global climate record because they can provide the longest records for the last interglacial period, up to 250,000 years.

Description and NSF Role

The Paleoclimates from Ice Sheets activity presents a rationale for carrying out an international collaborative deep drilling and research program in Greenland with several European countries. The GISP I deep core was 2037 meters long and 90,000 years old, and was an excellent initial step towards a detailed analysis. The goal of GISP II will be to drill a 3200 meter core in central Greenland that would represent a climatic and atmospheric record of 200,000 years, extending into the last glacial period. Such an ice core would provide an excellent record for studying climatic variations and determining the causes of major climatic events.

The analysis of ice cores requires coordinated and cooperative involvement in several scientific disciplines including climatology, meteorology, geochemistry, geology, geophysics, and glaciology. Detailed analyses of these cores, including an identification and dating of major events, must be done in order to establish a reference core. After the GISP II ice core has been retrieved, the drill hole can be used to obtain valuable information such as temperatures, shear strain rates, and bedrock samples. In addition, closures and tilts in boreholes can provide very important information about the rheological properties and iceflow characteristics.

Interagency Cooperation

NSF is the only Federal agency supporting ice core analysis. The U.S. Geological Survey (Tacoma, Washington) has been actively involved in the site selection (airborne radar) survey.

International Participation

NSF will continue to lead in the GISP II program and in coordinating with Danish, French and Swiss participants. In GISP I, Danish scientists provided the deep drilling and oxygen isotope analyses through the University of Copenhagen. The Swiss contributed to drilling technology and performed carbon dioxide and other gas analyses. Similar international contributions are expected for GISP II with the addition of a French contribution to chemical analyses.

OCEANIC RIDGE CREST PROCESSES

Purpose

The objective of the ocean ridge crest processes program is to examine and quantify the processes at sea-floor spreading centers caused by the formation of new oceanic crust. Specific goals of the Program are:

1. To determine the temporal and spatial scales of volcanic activity;
2. To quantify the chemical flux to seawater which results from hydrothermal circulation in the oceanic crust;

3. To identify the factors which control the biological colonization and composition of hydrothermal vent communities.

Evidence of Need

Oceanic ridges, or spreading centers, are a major component of the plate tectonic system that creates and modifies the surface of the earth. They are the dominant sites for the transfer of heat and chemical elements from the earth's interior to the surface--primarily by volcanic and hydrothermal processes. Recent research using deep-diving submersibles has documented the importance of hydrothermal circulation in controlling the long-term chemistry of seawater. The discovery of actively forming metal-rich sulfide ore deposits and extensive communities of benthic organisms supported by a chemosynthetic food-web was followed by initial chemical and geologic research.

Recent developments in technology allow an integrated and global study of geologic, chemical and biological systems at ridge crests. Advanced multichannel reflection systems and ocean bottom seismometers can be used to image the horizontal and vertical dimensions of crustal magma chambers. Advanced side-scan sonars and swath-mapping bathymetric systems can be used with remotely operated photographic systems to map the distribution and relative ages of lava flows and crustal faults which control the location of hydrothermal systems. Ocean bottom observatories can be deployed to record the temporal changes in hydrothermal flow rates and chemistry, as well as perform in situ experiments on vent communities and organisms.

The need for coordinated and integrated study of ridge crest processes was defined in the Joint Oceanographic Institution publication, "The Ocean Crustal Dynamics Program Plan for the 1980's". The concept was also endorsed by the Board on Ocean Sciences and Policy of the NAS and the Advisory Committee of NSF's Ocean Sciences Division. The NAS convened a workshop in April, 1987 to examine priorities in the program.

Interagency Cooperation

Programs to study limited aspects of ridge crest processes are supported by ONR, NOAA, and USGS. These programs are primarily guided by resource assessment within the Exclusive Economic Zone and have involved limited participation of academic scientists. The April 1987 NAS workshop examined mechanisms for more formal coordination.

International Participation

Active national programs for studying ridge crests and hydrothermal vents presently exist within France and Canada. Ridge Crest Studies are a major initiative within the U.S.-French cooperation in Oceanography bilateral agreement, with major field programs scheduled from 1990 to 1992. Canadian involvement would be focused in northeastern Pacific.

SOLID EARTH STUDIES

Purpose

The purpose of the Solid Earth Studies component of the Global Geosciences Program is to exploit the new scientific opportunities made available by recent technical and intellectual advances that now allow geological and geophysical phenomena and processes to be viewed from a global perspective. The observations promise improved understanding of the solid earth, its deep structure and composition, and the active geophysical and geochemical processes that over time have lead to the present distribution of oceans and continents. The activities all focus on a global perspective, are cross-disciplinary in character and require international scientific collaboration.

Evidence of Need

The rapid development of plate tectonic models has precipitated an urgent need to test the various hypotheses by using the natural laboratory of field geology and geophysics. Studies must be global in scope, interdisciplinary in nature and coordinated with the efforts of other federal agencies and international scientists.

For the first time realistic multidimensional computer models can be constructed and large data sets may be stored on globally coordinated data bases. The availability of distributed networks interlocked with the computing power and data bases will greatly expand the opportunities for independent researchers and their students. There is a growing need for new Data Management Centers such as the one for seismic data to be managed by the Incorporated Research Institutions for Seismology.

Description and NSF Role

Plate tectonic theory explains the origin of such major features as the continents, oceans, and mountain belts as consequences of a single global comprehensive process. The theory emphasizes the importance of integrating regional knowledge and helps to explain such varied phenomena as the geochemistry of the oceans, the occurrence of earthquakes, and long term variations in the earth's climate. A central theme of global studies on the solid earth sciences is to quantify the dynamic processes that govern the evolution of the earth and its surface features. Technological advances indicate that we are now on the threshold of new discoveries in a number of areas that include the following:

> A global network of digital seismographs will image the earth's interior and the distribution of forces driving plate tectonics. Such data are basic to understanding the origin of

earthquakes, volcanic eruptions and the origin of the earth's magnetic field.

The DoD NAVSTAR Global Positioning System (GPS) now makes it possible to observe the crustal deformation that currently occurs at plate boundaries and within the continental plates. The GPS will also help to calibrate tide gauges and help resolve the respective importance of tectonics and climate in sea level changes.

New techniques in isotope geochemistry, paleomagnetism, global correlation of sea level changes and identification of catastrophic events such as meteorite impacts and major volcanic eruptions will increase the resolution of the geologic time scale.

Layered fossil-bearing sediments are a source of data to test models of environmental change. Recent advances including computer models of regional deposition patterns, ocean and atmosphere circulation, seismic stratigraphy and remote sensing permit new global synthesis of the history of change at the earth's surface.

Satellite based-measurements include use of multispectral imagery of the earth's surface to map subtle changes in surface morphology, the Geopotential Satellite to map the earth's magnetic and gravity fields and application of the Shuttle Imaging Radar to map buried geological structures. The synoptic observations yield insights to fundamental questions such as the origin of the earth's magnetic field and the detailed history of recent global faulting.

In the areas of solid earth studies NSF makes available to the academic community computing equipment and resources needed for data analysis and modelling, and supplies the funds for the purchase of instrumentation and special facilities such as the Global Digital Seismic Network and Global Positioning instrumentation. Cross-disciplinary activities are encouraged through collaborative grants and workshops. NSF takes a leadership role in organizing and supporting international cooperation and exchange.

Interagency Cooperation

A Memorandum of Understanding exists between NSF, DARPA and the USGS for the Global Digital Seismic Network activities. NSF is responsible for instrument development, procurement and upgrading and cooperates in the collection and distribution of data. The USGS operates the seismic stations and currently collects the data from the world wide network. DARPA provides access to world wide seismic array data through its Center for Seismic Studies. The

Global Positioning Satellite activity is a multi-agency program with joint interest from NASA, NOAA (NGS), USGS and DoD (DMA). At present a formal MOU is being negotiated and there has been good cooperation in the planning of projects and the sharing of facilities.

International Participation

Australia, Canada, China, France, Germany, Japan and ORPHEUS (an organization of 15 west European countries) have joined with the United States in a Federation aimed at standardization of digital seismic networks. IRIS and the USGS are the U.S. representatives. The Federation has been recognized by the International Commission on the Lithosphere and the International Union of Geologists and Geophysicists, and the International Association of Seismology and Physics of the Earth's Crust.

ICSU's International Lithosphere Program has research objectives consistent with those of NSF's Continental Lithosphere Program.

NSF supported an international workshop on Global Sedimentary Geology in August, 1986 with the International Union of Geological Sciences (The Global Sedimentary Geology Program: Report of an International Workshop).

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Statement of

Edward M. Davis

President
American Nuclear Energy Council

For the Record of the
Senate Committee on Energy
and Natural Resources
Hearing on
the Global Warming Trend
and
S.2667, The National
Energy Policy Act of 1988

August 11, 1988

This statement is submitted for the record of the Senate Energy and Natural Resources Committee by Edward M. Davis, president of the American Nuclear Energy Council. The Council's membership includes nuclear utility companies, utility service companies, manufacturers and equipment suppliers, architect-engineering firms, Department of Energy contractors, and uranium producers as well as other fuel cycle and waste management organizations.

The Energy and Natural Resources Committee is to be congratulated for its central role in recognizing the fundamental implications of the global warming trend for our national energy policy. Moreover, the sponsors of S. 2667, The National Energy Policy Act of 1988, should be commended for their initiative in introducing this very comprehensive legislation that recognizes the need to formulate our national energy policy to reduce the generation of both carbon dioxide and trace gases.

S. 2667 explicitly recognizes nuclear energy as playing a critical role in mitigating the greenhouse effect by establishing an invigorated advanced reactor research and development program under the U.S. Department of Energy. The legislation also recognizes the importance of attacking the greenhouse problem on several fronts, in that it includes comprehensive language on basic science initiatives, conservation, renewable energy, coal, natural gas, tropical forest restoration, international cooperation, development assistance and world population growth.

Albert Einstein once said, "I never think of the future. It comes soon enough." In terms of climate change and meeting electricity needs, the future will come soon enough -- perhaps sooner than we're now prepared for. So America must think about the future now and begin implementing national policies necessary to address these problems. Finding solutions to the global warming trend will require the kind of foresight that is the foundation of this hearing. And it will require effort -- and compromise -- by a number of Congressional Committees and divergent interest groups.

Just as the changes now affecting the global climate have come about over many years as a byproduct of changes in the culture and industrial infrastructure of nations, it will take years to achieve solutions. The United States will be forced to re-examine its energy policies and adjust its energy mix to retard or stabilize global warming -- and, just as importantly, to maintain economic and energy security.

This statement does not reflect an expert's knowledge of the global warming trend. Neither does it advocate a national energy policy that abandons the use of any fuel source in favor of another, because the widest possible range of energy options must be used. Any combustion of fossil fuels contributes to the greenhouse effect, but the use of fossil fuels cannot be avoided in an industrialized nation, as, for example, they are essential to transportation and heating. There is, however, one area in which the United States does have an established option, and that is in the area of electricity generation -- and that option is nuclear energy.

A prudent society should have a balanced national energy policy -- one that draws on a variety of energy sources. To alleviate the greenhouse effect and to meet our growing demand for electricity, we believe that nuclear energy will have to be revitalized. The need for a coherent energy policy will require groups that have opposed nuclear energy to reconsider their opposition in light of this environmental problem. No single energy source created the greenhouse effect, and we must not dismiss any single source if the nation is to solve the problem and maintain our standard of living.

NUCLEAR ENERGY MEETS OUR ENERGY AND ENVIRONMENTAL NEEDS

Nuclear energy is a mature, proven, successful technology that meets America's growing electricity needs without contributing to the greenhouse effect. Today, 109 nuclear reactors provide almost 20 percent of the nation's electricity. Since 1973 an investment of approximately $130 billion in these facilities has paid off handsomely by displacing about 3.5 billion barrels of imported oil that would have exacerbated the greenhouse effect. These benefits will continue in the future because these nuclear plants have generated only a small percentage of the total amount of electricity they will produce in their service lifetimes.

Nuclear energy is an environmentally clean source of electricity. Unlike fossil fuels, nuclear energy generates no carbon dioxide. And as you are aware, carbon dioxide has been identified as a major cause of the greenhouse effect.

Fortunately, the environmental advantages of nuclear energy are becoming more widely acknowledged and appreciated. The greenhouse effect is causing one-time opponents of nuclear energy to thoughtfully ask themselves if there is a future for this energy source -- and, increasingly, the answer is "yes." For example, in the March 88 issue of NATURE magazine, the editors argue that anti-nuclear environmental groups may "find themselves differently impelled if it becomes clear that the only economically feasible way of mitigating the damage that might be done by carbon dioxide is to moderate the use of fossil fuel." The editors predict that international negotiations to achieve this action will be necessary, and that "even the most reluctant communities will begin building nuclear power stations again."

But environmental support for clean nuclear energy existed long before the greenhouse effect became front-page news. Few people may remember that the California Sierra Club, and its most well-known board member, Ansel Adams, the noted nature photographer and naturalist, advocated nuclear energy as an ecologically superior energy alternative. If he were living today, Ansel Adams would likely see the greenhouse effect as further evidence for fostering the use of nuclear energy.

Today, all Americans must be concerned about the effects of global warming on our environment and on our society. And all Americans -- including nuclear energy's opponents -- must be open to considering every energy source as a valuable component of a balanced national energy policy that is ecologically and economically sound. Today, nuclear energy is no longer an option, it is an imperative -- in light of the greenhouse effect, the rising level of oil imports and the increasing demand for electricity.

AMERICA'S ELECTRICITY DEMAND IS GROWING

At the same time scientists are researching the greenhouse effect and identifying solutions to alleviate this trend, the nation's demand for electricity continues to grow. Consider these facts:

- Since 1973, the Gross National Product has grown by 38 percent, while electricity use has grown 43 percent. Clearly, economic growth requires a growing supply of electricity.
- Since the economy emerged from recession in 1982, electric sales growth has averaged 3.3 percent a year. In 1987, alone, electricity sales increased 4.5 percent -- more than double the estimate of U.S. Department of Energy.

The reality of this growth in electricity demand is staggering. The Department of Energy reports that the United States faces a gap of 100 gigawatts between our planned capacity and projected electric demand by the year 2000. To illustrate the magnitude of this shortfall, 100 gigawatts is more electricity than what is now generated by all of the nuclear plants in the nation.

The simple fact is that the American economy, like the economies of all industrialized nations, is steadily becoming more electricity-intensive. If the nation is to have continued economic growth, additional electrical generating capacity will be needed.

Importing more foreign oil is neither an ecological nor economic answer. Today, the United States imports almost 40 percent of its oil. A 1987 report by Georgetown University's Center for Strategic and International Studies warned that imports could approach the 50-percent level by the mid-1990s, and that half of the projected increases will come from electric utilities. Ironically, utilities' plans for widely available energy alternatives -- coal and nuclear -- are lower than at any time in the past decade. Further, the low oil prices we currently enjoy cannot be taken for granted in the future. In actuality, today's low prices sow the seeds for high prices tomorrow by encouraging oil use, by shifting demand to overseas sources, and by lulling our consumers, industries and government into false complacency about energy vulnerability. And there is no escaping the fact that oil is a fossil fuel that injects carbon dioxide into the global greenhouse.

Other options exist for alleviating the greenhouse effect but, either together or individually, they are not a panacea for a world that is growing warmer and demanding more electricity. Conservation can help reduce demand, but it cannot offset our entire need in the years ahead. Cutting production of ozone-destroying chlorofluorocarbon gasses can help, but any results will be long-term because these compounds remain in the atmosphere for decades. Preserving the world's tropical forests may help, but will not alone solve the problem either.

Clearly, no single alternative presents a complete solution for alleviating the greenhouse effect. Conservation, renewable energy sources, and nuclear energy, as well as appropriate use of fossil fuels, must all be included in a balanced energy policy that meets our environmental and economic needs.

THE FUTURE FOR THE NUCLEAR OPTION

A revitalized nuclear energy option that can help to reduce the greenhouse effect and, at the same time, meet the nation's growing demand for electricity, depends on congressional action in three areas:

- a reasonable and efficient process for licensing nuclear energy plants;
- implementation of legislation that resolves the issue of nuclear waste disposal; and
- a continued federal commitment to developing advanced reactor technologies.

1. Standardization and Licensing Reform

The Atomic Energy Act of 1954 requires that nuclear plants be licensed twice -- first for construction and subsequently for operation. This regulatory requirement is inherently flawed because it encourages plant construction before the design is completed. The drawbacks are severe: major design decisions are made after construction is underway, driving up construction costs. In addition, the Nuclear Regulatory Commission makes safety-related decisions while plants are under construction and orders further design changes, creating further delays and cost escalations.

Congress must continue to act on legislation providing for standardized designs and establishing a one-step licensing process, in which a complete and pre-approved design is submitted before construction is begun. Such legislation is needed to prevent the higher costs and delays caused by the current licensing process. In this context, we are encouraged by the recent Senate action adopting the McClure Amendment to the NRC

Authorization Act. The NRC should stand ready to move forward quickly with a draft proposed rule on standardization and licensing reform.

2. Nuclear Waste Disposal

The National Waste Policy Act of 1982 created a legislative solution for safe disposal of waste created by nuclear energy plants. This landmark legislation was reaffirmed in 1987. The United States has the technological means to safely dispose of spent fuel and waste, and it is essential that the Department of Energy implement this legislation in an expeditious manner to ensure continued development of nuclear energy.

3. Advanced Nuclear Reactors

The greenhouse effect is gaining visibility at a time when the nuclear energy industry is achieving significant advances in operating existing nuclear power plants and developing a new generation of power plants. This vigorous development effort to raise all U.S. nuclear plants to an unparalleled standard of excellence is a prerequisite to reopening the nuclear option, that is, to strengthening confidence in nuclear energy so that there is a national will to move ahead again. Progress in this area is encouraging, and it is not too early to set goals for development of the new reactor systems which will reopen the option and to press on vigorously with those developments.

Congress has indicated its commitment to the future of the nuclear option by appropriating funds for research and development of the next generation of nuclear reactors. For Fiscal Year 1989 this amount will be approximately $80 million. These funds will help refine technologies that will lead to nuclear energy plants that further enhance the established safety and operating records of existing plants. Over the long term, it is essential that funding for advanced reactor technologies be maintained.

The goal for these new systems is centered around safety. Although from a public safety perspective the record of the present light-water cooled plants is unmatched--not only avoiding harm to the public but saving many lives each year as compared with other methods of generating electricity--major advances in safety can still be made. The key to advance in safety is the human factor, so strongly identified by the Kemeny Commission that investigated the Three Mile Island accident as the underlying cause of the accident. The centerpoint of the industry's "drive for excellence" for the country's operating nuclear power plants is the human factor--better training, better procedures, improved control room interfaces, advanced diagnostic aids, human performance improvement guidelines, and maintenance guidelines.

But significant improvements can be made by introducing additional passive safety features into new designs. Such features reduce reliance on active equipment to respond to emergency conditions, substituting instead additional intrinsic characteristics such as gravity cooling, natural circulation, intrinsic heat sinks, and natural "governors" which cause reaction rates to slow down when temperature or power speeds up.

Each advanced system -- the advanced light-water reactor (ALWR), the liquid-metal reactor (LMR), and the high-temperature gas cooled reactor (HTGR) -- has incorporated such passive safety features. Taken to their full extent, the end result is that operators need not act in hours but in days to respond to a serious accidental condition such as a loss of cooling or failure of the reactor shutdown systems. This is the ultimate response to the human factors issue which makes the training and other aids easier and surer to implement.

It is clear that the framers of S. 2667 recognized many of these facts in conceptualizing this legislation and in drafting the advanced civilian reactor programs title. The nuclear industry is reviewing that title with some interest and will submit detailed comments at a later date.

PUBLIC SUPPORT

Finally, and equally important to the future of nuclear energy and its contributions to alleviating the greenhouse effect, the American public and the scientific community recognize that this energy source will be a vital contributor to our nation's energy future. A national poll conducted in May found that 81 percent of those surveyed believe that nuclear energy will be important in meeting our electricity needs, and 78 percent believe it is likely that additional nuclear facilities will be required.

Last year, a national sampling of scientists listed in "American Men and Women of Science" revealed that 88 percent believed that nuclear energy will be essential to fulfilling America's demand for electricity in the years ahead. Significantly, this survey -- and a second 1987 poll of engineers and scientists selected from the readership of "Scientific American" -- found that almost 70 percent of the respondents considered the current generation of U.S. nuclear reactors safe.

The efforts of the Energy and Natural Resources Committee to deal with the global warming issue in a comprehensive and forward looking manner are to be commended, and the American Nuclear Energy Council appreciates this opportunity to submit the views of the nation's nuclear energy industry. Much remains to be learned and understood about the greenhouse effect and its far-reaching impact on ours and other societies. But one message should be clear: Americans and citizens of other nations cannot cling to the energy patterns, policies and prejudices of the past.

The American public, the scientific community and the nuclear energy industry are ready to move ahead with solutions to stem the greenhouse effect and preserve our economic and energy security. The industry is committed to assuring that nuclear energy will be a safe and economically viable component of a national -- and international -- solution.

The enactment of comprehensive legislation leading to the development of a balanced national energy policy that includes an expanded role for environmentally clean nuclear energy is an essential first step in preserving our environment and our standard of living for the next generation of Americans.

Submitted for the record

STATEMENT BY DALLAS L. PECK, CHAIRMAN, COMMITTEE ON EARTH SCIENCES, FEDERAL COORDINATING COUNCIL ON SCIENCE, ENGINEERING AND TECHNOLOGY

Hearing Before The
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

AUGUST 11, 1988

Mr. Chairman and Members of the Committee, I am pleased to provide this statement as the Chairman of the Committee on Earth Sciences.

Dr. William Graham, as the President's Science Advisor, formed the Committee on Earth Sciences within the Federal Coordinating Council on Science, Engineering and Technology (FCCSET) in April 1987. I serve as Director of the U.S. Geological Survey, a member agency of the Committee on Earth Sciences, and I was appointed Chairman of the Committee in October 1987.

The Committee is charged with coordinating all earth science activities of the Federal agencies, with "the purpose of increasing the overall effectiveness and productivity of Federal research and development efforts directed toward an understanding of the Earth as a global system."

I would like to touch on two examples that indicate the complexity of this endeavor. Only a decade ago, atmospheric and oceanic scientists were trying separately to understand and model the physics of a South Pacific ocean oscillation phenomenon known as El Niño, whose recurring disruption of precipitation patterns and ocean temperatures has multibillion-dollar international economic consequences. Neither the oceanic nor atmospheric models could generate conditions resembling those of the El Niño southern oscillation. It was not until some bright scientists coupled models simulating key processes in both the ocean and atmosphere, that the oscillation appeared in the model and the physical basis for the El Niño was deciphered. A partnership between the fields of oceanography and atmospheric science achieved this goal.

Another example relates to that most famous of greenhouse gases, carbon dioxide (CO_2). The amount of new CO_2 found within the atmosphere each year is approximately one half the amount that is emitted as a result of burning fossil fuels. The atmospheric concentration of CO_2 is controlled by a complex series of interactions between the atmosphere, land, and oceans. Oceans may absorb a quantity of CO_2 equal to half the annual emission generated by the consumption of fossil fuels. The transfer of CO_2 from the atmosphere to the oceans is controlled largely by the biology of singlecelled plants in the oceans' surface waters. Therefore, in order to understand the fate of half of the CO_2 produced by human activities, coordination of research efforts is required among the disciplines of atmospheric chemistry, biology, and oceanography.

If we are to progress toward reliable predictions of global environmental conditions, it is imperative for many disciplines to work together in an unprecedented way. In the U.S. science system, this implies collaboration among the many agencies that perform and fund earth-science and ecosystem research and observation.

Reflecting the need for broad community involvement, the Committee on Earth Sciences is composed of senior-level representatives from 11 Federal agencies: the Departments of Agriculture, Commerce, Defense, Energy, Interior, and State; the Environmental Protection Agency; the National Aeronautics and Space Administration; the National Science Foundation; the Office of Management and Budget; the Council on Environmental Quality; and the White House Office of Science and Technology Policy. The National Climate Program Office is represented on the Committee at the staff working group level.

Partnership with other U.S. science organizations and with other nations is essential for progress in global-change research. The Committee on Earth Sciences has linked its planning process closely to the National Academy of Sciences' Committee on Global Change. That Committee, whose members have contributed world leadership to the conception of the International Geosphere-Biosphere Program, are currently developing specific recommendations for the U.S. contribution to that program.

The international and the U.S. global-change research programs will seek to describe and understand the interaction of physical, chemical, and biological processes that regulate the total Earth system, the environment that it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human activity. This is a scope that goes significantly beyond what traditionally has been studied under the heading of "climate," although climate is a central element of the program. The Committee, working with the National Academy of Sciences' Committee on Global Change, has identified seven science areas that need coordinated study:

> **Biogeochemical Dynamics**--The study of the sources and sinks of key chemicals in the environment and their interactions within the Earth system with particular focus on oxygen, nitrogen, sulfur, and phosphorous.

Ecological Systems and Dynamics--The study of the responses of ecological systems to changes in global environmental conditions and of the influence of biological communities on the atmospheric, climatic and oceanic systems.

Climatic and Hydrologic System--The study of the physical processes that govern the climate and hydrologic system.

Human Interactions--The study of the impact of human activities on the global environment and the impact of changing global conditions on human activities.

Earth System History--The study of the natural record of environmental change as recorded in the rocks, terrestrial and marine sediments, glaciers and ground ice, tree rings, and other direct or proxy documentation of past climatic conditions.

Solid-Earth Processes--The study of solid-earth processes that affect the life-supporting characteristics of the global environment and especially those processes that take place at the interfaces between the Earth's surface and the atmosphere, hydrosphere, cryosphere, and biosphere.

> **Solar Influences**--The study of the response to changes in solar trends, including the responses to environmental variations in solar output and the Earth's orbital elements.

As its' first step in organizing the Federal contribution to this broad scientific effort, the Committee on Earth Sciences has undertaken an analysis of existing programs of the Federal Government so that we will begin with accurate knowledge of our current programmatic foundation. Subsequent steps will be to establish science goals and priorities and then to establish a sequence of steps to achieve those goals. The agencies have agreed to work together in an effort to increase overall effectiveness and productivity of the Federal science effort, but will develop their own budget initiatives according to the traditional budget process. I am pleased to report that the Office of Management and Budget (OMB) and the Committee on Earth Sciences have been working effectively together to ensure that budget initiatives in the global-change arena receive coordinated treatment at OMB.

The 11 agencies of the Committee have compiled a summary of their global-change programs for Fiscal Year 1989, using the President's Budget as the reporting base. The programs are being analyzed in the form of a crosscutting matrix, which was designed to show how each agency is addressing the seven science elements described above. For each of these science areas, the agencies have described three key programmatic activities: research, long term observations, and data management.

Our analysis and compilation of agency submissions is still under way, but I can report approximate totals at this time. We defined two major reporting categories:

contributing activities--justified for reasons other than global change and which, by themselves, do not contribute directly to our understanding of global change but which, if they did not currently exist, would have to be created as part of an overall global-change program;

focused activities--address global-change specifically or extract global-change information using results from contributing programs.

It is useful to think of the contributing programs as the foundation upon which the focused programs are built.

In the focused program category, the agencies have requested approximately $100 million for Fiscal Year 1989. In the contributing category, the figure is roughly $1 billion. When we have completed our analysis and resolved inconsistencies in the reports of the agencies, we will share the details with congressional staff.

The coordinating program for the international effort is the International Geosphere-Biosphere Program (IGBP), which was endorsed for sponsorship by the International Council of Scientific Unions (ICSU) in 1986. ICSU has established a Special Committee for the IGBP and a Science Advisory Council. The first meeting of the Science Advisory Council is planned for late October of this year in Stockholm. We plan for three representatives of CES agencies and one representative from CES staff to participate in this meeting. ICSU is a non-governmental organization, but has been responsive to a suggestion by Dr. Robert Corell of the National Science Foundation that the Stockholm meeting is an ideal opportunity for representatives of governments to meet together to begin the process of coordinating science programs among nations.

One of the great challenges of the interdisciplinary and international program which is envisioned is the systematic provision of information about the global environment for scientists' use. As things stand right now, we have a relatively poor capability to observe large-scale environmental conditions and, more particularly, to document changes in conditions over time spans of decades. Recognizing this challenge, Dr. Thomas Pyke of NOAA convened an Interagency Working Group on Data Management for Global Change. The Committee on Earth Sciences has established a functional linkage with that Working Group, which has already established the capability for agencies to exchange electronic information about each other's data holdings. They are working on establishing direct computer connections between the CES agencies and establishing common pricing and data exchange policies. All these efforts are aimed at establishing smooth exchange of information among agencies and among disciplines, with a minimum of effort on the part of the scientists who need the data for their research.

In summary, the Committee on Earth Sciences has accomplished a great deal toward unifying the U.S. Federal program that will, we are confident, make a major contribution toward international understanding of our changing global environment.

Mr. Chairman, thank you for the opportunity to provide these comments for the record. The Committee on Earth Sciences will be available to you and the members of your Committee for any further questions both now and in the future.

National
Democratic
Policy
Committee

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Testimony To The

SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

hearing on the

Greenhouse Effect and Global Deforestation

Submitted by the

NATIONAL DEMOCRATIC POLICY COMMITTEE

by Carol White

September 20, 1988

Thank you, Mr. Chairman, for the opportunity to testify before this committee on the problem of deforestation. There is increasing evidence that deforestation is a prime cause of devastating shifts in weather patterns, and certainly one of the direct contributory causes of the severity of the devastating floods in Bangladesh.

We keep hearing the refrain that such maladies are the result of "too much" development. In fact, it has been the result of imposed economic policies which have UNDERMINED development which has caused such problems. International financial institutions such as the IMF and World Bank have played a major role in this policy of enforced backwardness. I want to focus my remarks on the economic policies which are denuding the Amazon rainforest.

The deforestation of the Brazilian rainforest has reached such serious proportions, that it is now estimated that at the present rate of burning, the whole of this irreplaceable resource will have been destroyed within twenty years. The consequences of destroying large areas of tropical rainforest are now being visited on us, in the form of severe alternations of weather-- from extreme drought in the temperate zone to flooding in countries such as Sudan and Bangladesh.

In all probability, large scale deforestation in Brazil and in Indonesia have destabilized weather patterns on a global scale, displacing oceanic high pressure areas and tropical lows to create destabilization of the jet stream over North America and so on. There is no question but that removing rain forest exposes the poor soils on which they grow to rapid erosion. This results in water runnoff and uncontrollable flooding, and ultimately to the increase of desert area.

The dangers of the situation are receiving increasing attention internationally, not only among traditional ecologist circles. The question is: What is to be done about it? The most serious proposal now being floated is that some international body or conservationist group be given title to the rain forest area, in order to preserve them as a global resource. Once such proposal is a debt-for-rain forest swap arrangement. Such a proposal is a direct violation of the sovereignty of the nation of Brazil and is therefore to be rejected.

Implicit in the proposal is that the Brazilian nation has wantonly despoiled the biosphere. The truth is the opposite. The Brazilian government has been systematically forced to adopt a series of measures, which have resulted in the destruction of this resource by precisely those same forces who are now cynically attacking them. These same forces who now are sounding the alert about the destruction of the Amazon forests were the loudest in preventing the Brazilian government from introducing the kind of high-technology vectored development program, which would have allowed them to meet their financial obligations while raising the standard of living of the population, and maintaining the ecology of the rain forests.

Over the past twenty years, since the artificial raising of the price of oil--and then the increase of interest rates to usurious levels--the economy of Brazil has been under systematic attack. This was compounded when President Carter sabotaged Brazil's attempt to develop its own, independent nuclear industry. Similarly, plans to extend the Carajas project, in order to utilize these major iron, aluminum, manganese and titanium resources as a stimulus to the development of industry throughout Brazil, were sabotaged by international credit agencies, who demanded that Brazil adopt the profile of a colonial economy even though they are the world's fifth largest economy.

The Brazilians were instructed by international advisors from the World Bank and the International Monetary Fund to prioritize debt payment over internal development, and they were encouraged to devote such "natural resources" as their forest land biomass to fuel as an alternative to the development of nuclear energy and the importation of other fuels. Thus they fueled the reduction of pig iron with charcoal and they devoted farm land to the production of sugar cane in order to manufacture gasahol as a petroleum substitute. Where fertile farm land was still devoted to producing food crops, these crops were diverted to international markets, in order to realize the liquidity needed to meet debt service requirements.

The forests of Brazil were then turned over to a new class of farmers whose product would serve the internal market. These new farmers were induced to move from other areas to engage in a slash-and-burn form of undercapitalized agriculture and cattle-growing which could be sustained in one area for less than a decade before depleting the soil. At the same time, larger cartels also moved into speculative purchase of rain-forest land in order to reap the benefits of agricultural subsidies of various sorts.

The Amazon "cattle ranches" are mostly owned by large multinational corporations such as Nestle, Borden, Goodyear, Volkswagen, and ARCO. Each of these companies owns from a quarter of a million acres to several million acres of Amazon rainforest, and every year they burn huge tracts of their property. Raising cattle in the Amazon is a money losing proposition. The corporations don't intend to produce beef. Their enormous profits are made in land speculation and huge government subsidies, tax write-offs, and import duty exemptions.

What it boils down to is this. Much of the population who were enticed into areas such as Rondonia in Brazil, with the inducement that they would become independent family farmers, have ended up as virtual slave laborers in primitive mining ventures or working on these ranches. All are afflicted with tropical diseases such as Bubonic plague, Dengue fever, AIDS, and devestating new varieties of plague yet to be named, as well as more traditional diseases such as malaria.

This should be seen as part and parcel of a broader population policy, also being imposed upon Catholic nations such as Brazil. If these nations refuse methods of birth control such as abortion, then the same results will be achieved by imposing severe austerity upon their economies. The "surplus" population of more than a million Brazilians now being destroyed in the Amazon region, could have been productively employed if the development projects planned by the Brazilian President, Ernesto Geisel from 1974 to 1979, had not been deliberately sabotaged by Walter Mondale on behalf of the International Monetary Fund and the World Bank. In the more recent period, from August 1985 to April 1987, Dilson Funaro, the Finance Minister of Brazil attempted to renegotiate debt-payment terms in order to reinstitute a development policy for the shattered economy of Brazil. He was forced out office by the same banking circles.

These same circles now wish to appropriate the Amazon region to themselves, as a preliminary to returning Brazil and the rest of Ibero Americo to colonial status. They would subject the whole nation of Brazil to the same feudal relations now prevailing in areas of the Amazon being "farmed" by the multinational cartels, while "protecting" the trees of the rain forest. We certainly need to provide the nation of Brazil with the means to redevelop these areas, means which they would have had but for the deliberate policies of their creditors, which were intended from the first to not merely to collect its debt, but to destroy the very sovereignty of Brazil.

The following resolution passed at the September third and fourth Conference of the Schiller Institutes' Agriculture Commission, held in the United States in the city of Chicago, is submitted here for your consideration:

Whereas, The world climate system depends upon continued existence of the tropical rainforests--in particular those of Brazil and Indonesia, and

Whereas, these nations have been driven to exploit these resources because of intolerable economic conditions imposed upon them by the World Bank, and the International Monetary Fund, and others of their creditors, and

Whereas, these creditors, now claiming to recognize an impending ecological disaster, are attempting to seize the property of the nation of Brazil in return for protecting its resources;

Be it resolved that in order to protect the rain forests and to give the population of Brazil and other nations of the developing sector the opportunity to live in peace and prosperity, these nations will be offered low-interest credits to establish industry and establish appropriate farm lands for the populations now in these areas, and to reimburse all owners of rainforest property to the amount whic they paid for the land from their own funds (not at the present faked market values)p and that these nations be given additional funds for the rapid development of nuclear energy, massive infrastructure programs, and other advanced technologies.

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